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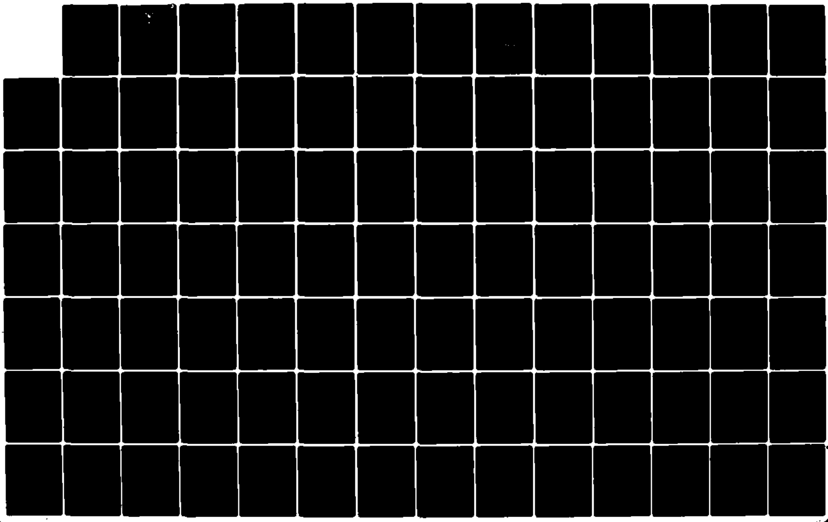

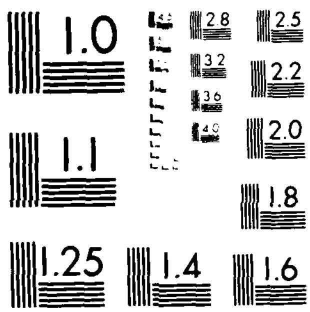

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ENERGY MANAGEMENT AND CONTROL
SYSTEM VERIFICATION STUDY

Keith E. Boulware, Captain, USAF
Gary C. Williamson, Major, USAF

LSSR 37-83

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Energy Management and Control Systems (EMCS) are being installed and operated throughout the Air Force. Millions of dollars have been spent on EMCS, but no study has conclusively proved that EMCS has actually saved the Air Force energy. This thesis used the Regression subprogram of Statistical Packages for the Social Sciences (SPSS) to determine if these systems are indeed saving the Air Force energy. Previous studies have shown that Multiple Linear Regression (MLR) is the best statistical predictor of base energy consumption. Four bases with no EMCS's (control bases) were utilized to verify that MLR was an accurate method for predicting energy consumption. Eight bases were selected that had an operational EMCS. Two EMCS bases were compared with one control base for each of four CONUS winter heating zones. The results indicated small (less than 2%) energy savings have occurred at half of the EMCS bases studied. Therefore, this study does not conclusively prove that EMCS's have saved energy on Air Force bases. However, the methodology developed in this report could be applied on a broader scale to develop a more conclusive result.

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ENERGY MANAGEMENT AND CONTROL
SYSTEM VERIFICATION STUDY

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering Management

By

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CHAPTER 1

INTRODUCTION

The research effort described on the following pages investigates the role of Energy Management and Control Systems (EMCS) in the energy conservation and efficiency programs of the United States Air Force. The question of the amount of energy actually saved by the EMCS component of these programs has remained unresolved, even though its answer is vital to management of future energy programs.

Problem Statement

General Problem. The U.S. Air Force has projected annual savings of over four million dollars from the employment of EMCS at 53 USAF installations. However, no solid data exists to verify these savings. There is acute Congressional interest in the amount of energy the EMCS's have saved (2). Consideration of normal USAF facility physical characteristics reveal the following specific factors that have prevented adequate verification.

Specific Factor 1. Adequate historical energy consumption data for individual buildings is generally not available because meters are not installed on most individual buildings on USAF bases. However, even if individual building data were available, the many specific differences

between buildings on different bases, and even between buildings on the same base, may invalidate generalization of the results to larger building complexes and entire bases. Base-wide energy consumption data is available but does not provide a convenient immediate reference for evaluation of energy savings. Changes in numbers, sizes, and characteristics of buildings may produce changes in energy consumption that should be considered for valid energy savings comparisons.

Specific Factor 2. Isolating the effects of EMCS is difficult where other ECIP improvements have been accomplished during or after EMCS installation.

Specific Factor 3. After considering Factor 2 above, an appropriate method to isolate EMCS energy saving effects would appear to involve metering a base or installation with EMCS turned off and on for similar periods. This cannot be accomplished without considerable calibration efforts. When EMCS is installed, some of the control system components are altered to accommodate the new equipment. Simply turning EMCS off does not necessarily return the control system to its prior state. All the EMCS influences would have to be disconnected and the control system recalibrated in accordance with the original design specifications (17).

Specific Factor 4. In addition to the above calibration problem, weather differences would be a significant factor in consecutive test periods with EMCS turned on and

off. Long test periods would help, but total heating/cooling degree days can vary considerably (up to 50%) even on a yearly basis.

Studies performed to date have failed to conclusively prove either the practicality or impracticality of EMCS. Several studies since 1978 have had widely varying degrees of support for EMCS (1). Some studies have been rejected after close scrutiny by high level staff members (5).

Statement of Objectives

The objective is to determine whether the Energy Management and Control Systems (EMCS) have saved energy in USAF facilities, and the amount of energy that has been saved. The specific sub-objectives listed below and the methodology explained in Chapter 2 are designed to overcome the above Specific Factors 1 and 2, while eliminating the impact of Specific Factors 3 and 4.

Sub-objective 1. To use historical data to develop a statistical model which predicts energy consumption. It must include both the previously validated energy requirement variables (Base Population, Facility Square Footage, and Heating/Cooling Degree Days), and moderating variables which account for energy conservation improvements other than EMCS.

Sub-objective 2. To validate the above model by comparing the predicted consumption with actual consumption on non-EMCS installations.

Sub-objective 3. To determine whether any savings has taken place by comparing the energy consumption predicted by the above validated model with actual energy consumption data for installations with an operating EMCS.

Research Question and Hypotheses

Question 1. What statistical model will best predict energy consumption as a function of energy requirement variables and moderating variables which account for ECIP improvements?

Hypothesis 1. Energy consumption predicted by the above model for non-EMCS installations is equal to actual energy consumption.

Hypothesis 2. Energy consumption predicted by the above model is greater than actual energy consumption for installations with an operating EMCS.

BACKGROUND

World

International economic development has been driven by the unrestricted availability of inexpensive energy. The Arab oil embargo of 1973 was a politically selective denial of petroleum products to countries supporting Israel. As a result, oil prices increased more than tenfold. The whole world's economy faltered, causing high unemployment and business slowdowns. This crisis resulted from the unbalanced geographical distribution of known oil reserves. Enhancing

the problem was the fact that about 25% of the world (West European industrialized nations, Japan, Canada, and the United States) consumes 80% of the world's production of petroleum products. These industrialized nations are highly dependent on imported oil, with some as much as 100% dependent. Dependence on imported oil is expected to increase, and the Soviet Union is expected to become an importer by 1985. There is a limit to how much petroleum is available, and it is estimated that the known petroleum reserves will last only until the year 2015 (29:p.1-2).

National Energy Perspective

The energy problem in the U.S. came from its dependence on petroleum, which represents only 7% of United States proven reserves. Although the U.S. represents only about 6% of the world's population, it consumes 36% of the world's petroleum energy. The United States produces only 17.6% of the world's crude oil which means it imports over 40% of its liquid petroleum needs. Of all the oil the U.S. imports, almost half is from the Arab nations which imposed the 1973-1974 oil embargo. The total U.S. energy demand is expected to increase from 38.7 million barrels of oil per day in 1980 to 50.3 million barrels per day by the year 2000. The era of inexpensive energy in the U.S. ended with the oil embargo of 1973 (3:1-28; 9; 29:pp.1-3 to 1-7).

Federal Government

The Department of Defense uses 2.5% of the energy consumed by the U.S. The Air Force used 154.4 trillion BTU's in FY 1980, which was 56% of the energy taken by DOD or 1.4% of the energy consumed by the United States (3:1).

In compliance with Executive Order 12003, the Department of Defense has established several energy conservation and efficiency goals. The facilities energy reduction goals, as compared to the FY 1975 consumption level, are as follows for existing buildings: 20% per square foot by FY 1985, 25% by FY 1990, 30% by FY 1995, and 35% by FY 2000. The goal for new buildings is 45% reduction compared to a similar building built in 1975 (3:iii,83).

Air Force

The Air Force consumes great quantities of energy to fulfill its goal of deterrence. Coal, oil and natural gas are the main sources of energy for the Air Force. The Air Force has reduced its consumption by 36% from FY 1973 to FY 1980, but total utility costs still have increased 136% from FY 1975 to FY 1980. Aircraft operations utilize 70.5% of Air Force energy, vehicle operations utilize 1.6%, while facilities use the remaining 27.9% (3:1-27).

Many programs have been implemented to save energy in facilities. The Air Force has reduced, through any and all means, total installation energy consumption by 27% from FY 1973 to FY 1980. Some typical energy conservation

investment programs (ECIP) conducted during this period included the following: building new heat generating plants; adding insulation in base facilities; installing sodium vapor lighting for base streets; placing new heating, ventilating and air conditioning (HVAC) systems in facilities; installing insulated windows; and establishing energy management control systems (EMCS) which all bases included as part of their energy projects (3:5-7).

Historical Overview of EMCS

In the early 1950's the forerunners of EMCS were developed. They basically consisted of a large central panel that had gauges and dials with relays and switches that could stop and start the attached equipment by a time clock. Each controlled point had separate electric or pneumatic lines which made it awkward and expensive. This system could handle only one building.

Time-sharing graphic displays came into being in the mid-1950's, reducing the size of the control consoles. The main unit, now called a central processing unit (CPU) instead of the central panel control, used hardwire logic circuits to store the values received from the remote points. The data could be displayed by these circuits instead of by dials and gauges. Similar circuits at the remote locations stored data, and transmission lines were shared. These units could monitor temperature and pressure, report abnormal conditions, start up and shut down equipment based on a time

schedule, and make adjustments on set points (i.e., changing temperature for night and day).

Multiplexed data transmissions came into being in the 1960's, allowing the field panel to convert the signals to a digital form for transmission to the CPU. The individual wires from each sensor to the CPU were replaced with a two or four wire cable. The field panel controlled each channel so that separate data could be simultaneously sent over these multiplexed channels.

The distance over which sensors could communicate was increased by the introduction of telemetry techniques developed from space probes and long-distance telephone lines. In fact, in the late 1960's the post office monitored buildings in Alabama, North Carolina, and Pennsylvania from Ohio using long distance telephone lines.

The advent of cathode ray tubes allowed many values to be shown on one device. The major problem was that it used hardwire logic which restricted the use to values already identified. Addition of sensor points required major rewiring of the console.

In the 1960's, transistors were replaced by computer chips which could each perform twelve different functions. Later development enabled performance of over 100 functions per chip. The first minicomputer was marketed in 1965, with the first true EMCS following in 1970. The software capability of a computer gave EMCS great flexibility for changing

needs. The console only had to be reprogrammed instead of rewired. The oil embargo of 1973 provided the impetus for large scale use of EMCS.

The cost of small scale computers decreased from $250,000 to a range of $2,000 to $25,000, making the purchase of an EMCS much more economically feasible. The estimated expenditure on EMCS in 1974 was $200 million, which is expected to rise by 1985 to 775 million dollars. This has been caused by the increasing energy cost and the decreasing cost of EMCS.

The past 30-year period has seen tremendous EMCS development from a simple monitor to a total facilities controller (22:3-7).

Present EMCS Status, Capabilities and Operations

The components of the EMCS are divided into two categories: hardware and software. The hardware consists of the central processing unit (CPU), the memory, the input/output devices and the input/output field interfacing devices (FID's). The software program tells the hardware what to do and how to do it.

The CPU and FID's are connected by a transmission line which uses multiplexing techniques to share a common channel. Sensors and controllers which monitor and/or control are wired into the FID's. The FID's (microprocessors or microcomputers) monitor the sensors and make routine

changes. The FID links the sensors and controllers and the CPU. The FID's take the data from the sensors and convert it into signals for CPU processing. Then the CPU can store the data, use the data for computer decisions, or display the data on the CRT to await operator decisions (15; 18; 22:8-18).

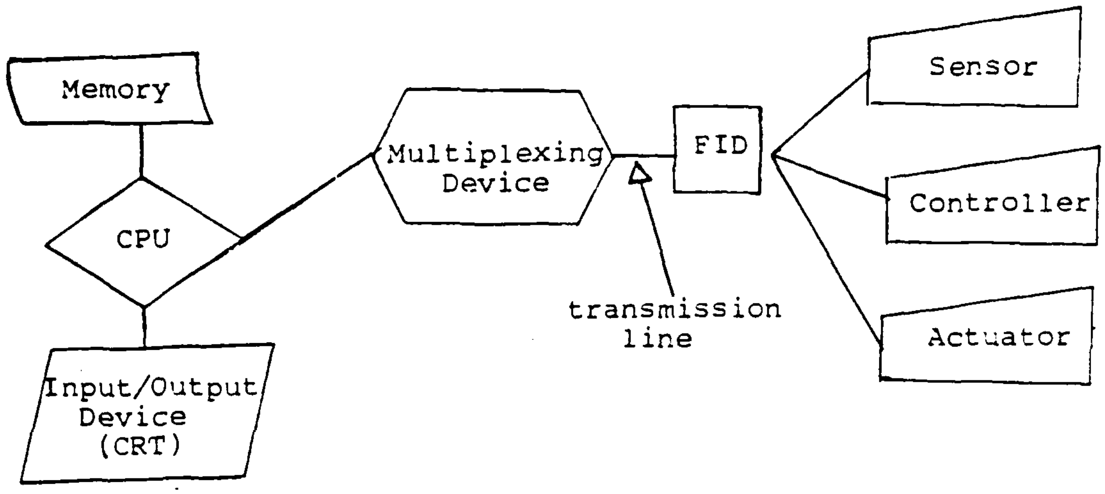

Figure 1. EMCS System Block Diagram

The EMCS is classified by three levels of capabilities and sizes. The overall capabilities include the following:

1. Level "A" EMCS (basic energy conservation) monitors and provides start and stop control of equipment.

2. Level "B" EMCS (maximum energy conservation) has a computerized system that allows the application of optimization programs.

3. Level "C" EMCS (all of B plus full engineering applications) has a computer control system that is capable

of all optimization programs plus providing significant maintenance and management capability (23:22-23).

The sizes are:

1. Large EMCS, in excess of 2000 sensor and/or controller points.

2. Medium EMCS, between 500 and 2500 sensor and/or controller points.

3. Small EMCS, 50 to 600 sensor and/or controller points.

4. Micro EMCS, less than 125 sensor and/or controller points (27:7-18).

The Air Force has all sizes and capabilities of EMCS. Some have been operating as early as 1977. The individual base installation costs of the EMCS have varied from $600,000 to $7,000,000 (21:7-11)

EMCS capabilities are listed below:

1. Time of day controls. The starting and stopping of equipment is based on the time of day.

2. Duty cycling. The shutting down of equipment for short planned periods during operating hours.

3. Demand limiting. The shutdown of selected equipment, through load-shedding operations similar to duty cycling, to insure the total electrical load remains below a set limit.

4. Optimum start/stop of equipment.

a. Morning warm-up of building during heating season. The equipment is started as close as possible to the occupied time.

b. Morning cool down of building during cooling season. Chillers or outside air are used only when needed.

c. Early shutdown of HVAC systems. HVAC system can be shut down prior to the vacant period.

5. Night temperature setback. Lowering the temperature set point when the facility is unoccupied.

6. Enthalpy economizer cycles. Determines when outside air can be justified to cool a building.

7. Hot/cold deck temperature reset. Minimizes the temperature difference between the heating and cooling surfaces of a dual duct HVAC system while meeting the total system load at a given time.

8. Chilled water temperature reset. Varies the chilled water temperature to meet the current cooling load.

9. Cooling tower optimization. Calculates the controllable parameter settings to use the lowest amount of energy.

10. Optimization of chiller loading. Distributes cooling load among chillers to produce most optimum operating conditions.

11. Carbon dioxide control. Determines the quantity of outside air needed according to the level of carbon dioxide in the building.

12. Gap control for self-heating buildings. Allows the conditions in a space to drift between set limits (6; 10:305-314; 11:E-Ed; 14; 22:30-44).

Common problems experienced with EMCS are as follows:

1. Long periods are often required to debug and fine-tune the system.

2. The system does not always meet the owner's requirements.

3. The system often does not perform its monitoring and control functions accurately.

4. Alarm signals are occasionally triggered by the EMCS when actual conditions are not out of tolerance.

5. The printer has low reliability, requiring excessive maintenance.

6. If power to the EMCS is interrupted, the EMCS cannot be brought back on line without considerable maintenance effort.

7. Many owners have found that, when expanding their EMCS, they can obtain the extra hardware from only the original manufacturer, and at an exorbitant price.

8. The EMCS's generally require more maintenance man-hours than other HVAC control systems.

9. In retrofit applications not all of the building system devices are compatible with EMCS's.

10. Through advertising, manufacturers often build up expectations of EMCS beyond actual capabilities (22:57-61).

U.S. House of Representatives Report

The House of Representatives' Subcommittee on Oversight and Investigations of the Committee on Energy and Commerce recently published a report on Federal Government energy waste. They criticized the Department of Defense's (DOD) ECIP and EMCS programs as being mis-managed and misdirected. They cite that the EMCS program, regarding energy conservation goals, ". . . has failed miserably to date because of significant project delays and operational problems [26:6]." Another report, briefed to the Facility Energy Steering Group (FESG), stated that delays averaged 20 months on 36 of the 40 EMCS projects under construction (24).

The Subcommittee reported diminishing energy savings in 1981. USAF installation energy consumption decreased only 1% from FY 1980 to FY 1981. Although they acknowledged early energy improvements are easiest to achieve, they criticized the Air Force's FY 1981 building conservation record as being the worst in six years.

DOD's failure to validate ECIP (including (EMCS) energy savings) was criticized. The Subcommittee cited a March 1982 letter from the Assistant Secretary of Defense for Logistics and Materiel Management stating that the Air Force has completed no EMCS validation studies.

The Subcommittee blamed base-level and higher-level management for continuing deficiencies in DOD's energy conservation program. The report stated that DOD

> . . . continues to rely on expensive ECIP and EMCS projects to meet its energy conservation goals while ignoring low-cost and no-cost conservation measures in many installations. Even within ECIP, auditors have found that 'projects with relatively low returns were being implemented before those with higher returns' in many cases [26:30].

One of the Subcommittee's recommendations was to initiate validation studies comparing actual and predicted energy savings from retrofit conservation measures (26:23-39).

EMCS User Satisfaction Study

This study was conducted for the National Bureau of Standards to determine whether 86 EMCS users were subjectively satisfied with their systems, and to identify characteristics of problem areas and successful areas of EMCS operations.

Twenty-nine percent of the users judged their systems unreliable. Eight identified problem areas are listed below in decreasing order to complaint frequency.

1. Manufacturer lack of dependability and inability to maintain operational system status. Inadequate documentation, service expertise, and service call response times were noted.

2. Proprietary design restrictions sometimes prevented users and technicians from obtaining needed documentation and training.

3. Software problems. There were some general problems, such as program failures and unsuccessful optimization programs.

4. There were some major lightning-caused failures and other transmission line noise effects that destroyed data.

5. Peripheral and other hardware problems included several complaints on printers and other output devices.

6. Spare parts supply problems included some delays of six weeks and a few delays of more than six months.

7. Some central processing unit problems occurred which were usually intermittent and hard to find.

8. The sensor problems that occurred all involved calibration drift.

Four factors appeared to positively affect reliability. Existence of (1) EMCS maintenance training and (2) in-house maintenance capability were found much more often among systems that were perceived to be reliable. (3) The third factor, which may be related to success of the first two maintenance factors, showed that for systems with optimizing capability, more systems were reported reliable than unreliable. (4) Age, as expected, was found to vary inversely with perceived reliability.

The following three factors did not affect perceived reliability: (1) type of facility, except for hospitals which showed higher reliability; (2) system manufacturer; and (3) Federal Government ownership (8).

In summary, the authors stated that their ". . . data suggest that EMCS maintenance training, in-house

maintenance capability, and reduced dependence on the system manufacturer may help improve user satisfaction [8:iii]."

A Review of EMCS Effectiveness

Recent experience with EMCS in both civilian and government applications have shown mixed results. Following is a review, in the civilian sector, of cost-effective and non-cost-effective EMCS features:

Guntermann (13) reviewed the cost effectiveness of the various energy management control system features. The potential energy savings depend largely on the types of systems to which the EMCS is being compared. For instance, as Guntermann points out:

> Beyond a doubt, most of the highly touted energy savings attributed to the addition of energy management systems have resulted from the addition of start/stop scheduling to HVAC systems that operated continuously.

Before energy conservation became important, most HVAC systems included manual stop/start controls, and thus often were left to run continuously. Simple seven-day time clocks, as are presently often installed, can produce large savings on those continuous systems. For example, the Austin company installed a time clock in its corporate headquarters in 1974, reducing its electrical consumption by 36%. The $3000 installation cost, resulted in energy savings of $11,000 for that year.

Installation of multiple time clocks (at $50) in individual facilities can cost much less than a central time

clock or an EMCS ($600-$25,000) because of the high installation costs of the interconnecting wiring. Those separate time clocks can present problems in the support of irregular activities. However, overriding timers can be installed at locations such as auditoriums to enable any occupant to start the system. The timer would then shut down the system automatically. This arrangement would cost less than either the continuous manning of a central EMCS or the requirement for maintenance personnel to go to the EMCS at the appropriate start/stop times.

A microprocessor or computer can provide three improvements over a standard time clock for HVAC system control. Since standard seven-day time clocks require manual adjustments for daylight savings time and holidays, these functions often are not done. Thus, either separate microprocessors or a central computer would save energy by automating these known seasonal variations. Another advantage of a microprocessor/computer is the ability to start/stop different portions of an HVAC system at different times. A time clock will usually start/stop an entire HVAC system at one time. For example, heating/cooling should start prior to the occupancy time. A computer can also optimize the lead time for heating/cooling systems based on the outside air temperature and the temperature of the mass inside the exterior walls. This would not only save energy but also improve comfort conditions at the start of a day. Guntermann

states that employment of small EMCS's that perform the above three functions can provide 5% to 20% more energy savings than simple seven-day time clocks. This energy savings is probably the most provided by any of the EMCS functions in existing buildings.

Another feature of EMCS is duty cycling, where such devices as fan motors are shut down for short periods. This reduces the total energy consumption in situations where a reduced average air flow rate is acceptable. Guntermann questions this procedure, "because there are better methods of accomplishing the same goals of saving energy and reducing maintenance costs." When the average air flow rate can be reduced, a reduction in fan speed will save more energy than intermittent shut-downs. This is because the power requirements for fan motors is a function of the cube of the fan speed. Duty cycling can also significantly increase maintenance problems and expense in both electrical and mechanical system components because of the high start-up stress on starters and drives (13).

Peak demand limiting is another potential area of energy savings, but again, EMCS may not be the most cost effective approach to the matter. The sophisticated EMCS demand calculations are of little benefit if few loads can be shed without sacrificing comfort or productivity. As in duty cycling, intermittent shut-down of such equipment as supply fans may not be as effective overall as other methods,

such as reducing fan speed for continuous operation. Reducing air conditioning at peak demand times is likely to reduce comfort levels because that is just the time when the air conditioning is most needed. However, chilled water storage could accomplish this peak demand limitation without sacrificing comfort. Shutting off electric water heaters during peak periods saves energy, but this can be done with time clocks as easily as with EMCS.

If lighting levels can feasibly be reduced, that should be done permanently, not just for peak demand periods. Photocells can also be used to reduce lighting in the presence of sufficient daylight. In a large building, an EMCS can save energy by controlling lighting according to the time of day for different functions and occupancy levels, as well as controlling the daylighting reductions.

Guntermann stated that "numerous temperature control modifications can be added to older HVAC systems to reduce energy consumption." He also said they ". . . can be installed at much less expense without EMS (EMCS) and save equivalent energy."

In summary, EMCS's can provide a limited amount of cost effective energy savings. There are four main categories of energy savings: load reduction, efficiency improvement, waste energy recovery, and operating time reduction. Of these, EMCS can only function in the last area, time control. It's most cost effective contribution is through the

three optimizing start/stop load-scheduling features discussed earlier. EMCS's other main cost effective function is optimum scheduled lighting control. Duty cycling, demand limiting, and temperature control were generally not considered cost effective functions for EMCS employment (13).

Previous EMCS Study

Alchian and Burns (4) studied the effectiveness and efficiency of EMCS with data available to 1978. Interestingly, the present urgent requirement for validation of EMCS energy savings is the same as that stated in the 1978 study. Alchian and Burns concluded that EMCS met the Air Force criteria for cost and energy savings. However, their study appears to be plagued with some of the problems that were described earlier in the problem statement.

Alchian and Burns stated that, up to the date of their study, the only analyses performed to determine EMCS effectiveness and efficiency consisted of engineering estimates or computer simulations. EMCS energy savings data for their study were obtained for individual facilities from base personnel. No explanation was given for the calculation of the energy savings numbers. The data were simply "considered valid" because they were required for congressional hearings and were subject to audit by the General Accounting Office (4:1-73).

Energy Forecast Model Developments

Tinsley (25) developed a statistical model to predict consumption of coal, oil, and natural gas at U.S. Air Force bases. His objectives included two points: determining the most appropriate statistical method for forecasting Air Force facility energy consumption (all non-electric energy), and identifying the most relevant independent variables for the statistical model.

He found multiple linear regression (MLR) to be the most appropriate method of building the model as long as information for the following important variables was available. The most relevant independent variables were facility square footage, base population, heating degree days, and cooling degree days. Tinsley used a common general format to set up the model for each base, and then used MLR analysis to compute the specific coefficients to fit a specific model to each base (25:5-99).

In an analysis similar to Tinsley's, Weck (30) developed a statistical model to predict electrical energy consumption at Air Force bases. His objectives included identifying the important variables and determining whether a linear relationship exists between electrical energy consumption and those variables.

Weck's results were also similar to Tinsley's. He concluded that MLR is the appropriate method to forecase electrical energy consumption at Air Force bases, based on

his literature review of previous electrical energy studies. Weck found the important variables to be the same four as in Tinsley's results. For the 15 bases analyzed, each of the MLR models were statistically significant, and all but three of the models included all four of those independent variables. Weck did find a multicollinearity problem between the cooling degree day and heating degree day variables. However, he concluded this multicollinearity would not degrade the model because high values of each of those variables usually do not occur simultaneously (30:16-65).

In view of Tinsley's research efforts and Weck's literature review, MLR will be assumed to be the most appropriate statistical method for the present EMCS study. The four variables they found most important will provide the starting point for building the model in the present EMCS analysis.

CHAPTER 2

METHODOLOGY

Scope

Due to the time available to complete this project, the number of installations studied were limited as much as possible while maintaining a statistically rigorous and broad geographical cross-section of the 48 contiguous states (CONUS). Because of availability of data, only USAF bases were considered. Eight test bases (with operational EMCS's) were selected according to the following criteria:

1. To obtain a broad yet structured cross-section of the CONUS weather conditions, the winter heating zone criteria, as depicted in Figure 2 was chosen. Two bases were selected from each of the winter heating zones I through IV. No EMCS bases were available in zones V and VI (19:p.2-21).

2. Energy consumption data had to be available for approximately two years before and two years after the EMCS operational date.

3. The EMCS at each base had to include at least 500 sensor and/or controller points (medium or large size EMCS). If more than two bases in a zone satisfied this requirement, the two bases with the highest number of points were selected as the test bases.

Four control bases (without operational EMCS's) were selected according to the following criteria:

1. One base was selected for each of the four winter heating zones containing test bases.

2. Energy consumption data had to be available for at least four years.

The winter heating zones are defined as follows (19:p.2-21).

TABLE 2-1

WINTER HEATING ZONES

Zone	Average Annual Heating Degree Days
1	0 - 2000
2	2000 - 4000
3	4000 - 6000
4	6000 - 8000

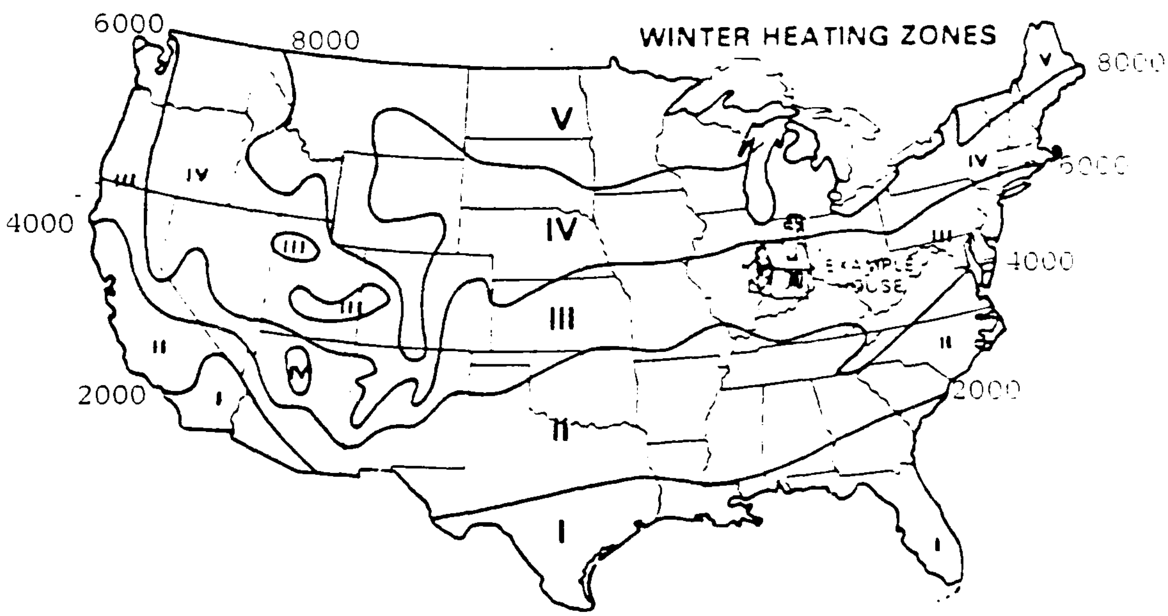

Figure 2. Winter Heating Zone Map

The selected bases are listed in the following table, with the column headings defined on the next page:

TABLE 2-2

EMCS AND CONTROL BASES

1 Base #	2 Test Bases	3 HDD	4 Z	5 Area	6 Pop	7 Cmd	8 Pts	9 Bldg
1	Kessler AFB MS	1549	1	8,983	14,370	ATC	2910	40
2	Lackland AFB TX	1520	1	10,602	30,322	ATC	4655	61
3	Charleston AFB SC	2146	2	4,011	5,403	MAC	655	37
4	McClellan AFB CA	2566	2	11,415	16,896	AFLC	505	24
5	McGuire AFB NJ	5139	3	6,191	6,276	MAC	595	22
6	Scott AFB IL	4855	3	5,589	9,738	MAC	1680	41
7	Air Force Academy CO	6973	4	7,372	8,719	ATC	2905	12
8	Offutt AFB NE	6213	4	10,104	34,061	SAC	746	42
	Control Bases							
9	Kelly AFB TX	1520	1	14,166	20,691	AFLC		
10	Langley AFB VA	3623	2	6,372	11,056	TAC		
11	Mountain Home AFB ID	5732	3	4,319	4,093	TAC		
12	Ellsworth AFB SD	7049	4	5,675	14,401	SAC		

1. Base $ - Base reference number used in the data files.

2. Base names of test and control bases.

3. HDD - Average annual heating degree days (28:iv).

4. Z - Winter heating zone.

5. Area - Total base facility square footage, in thousands, as of the end of FY 1982.

6. Pop - Base population as of the end of FY 1982.

7. Cmd - Major command to which the base is assigned.

8. Pts - Number of sensor and/or controller points attached to the EMCS (12).

9. Bldg - Number of buildings monitored and/or controlled by the EMCS (12).

Data Description and Collection

The required information discussed in this section includes the following data items: 1. base population; 2. facility square footage; 3. heating degree days; 4. cooling degree days; 5. energy factors (other than EMCS); and 6. energy consumption data in millions of British Thermal Units (MBTU). Monthly listings of the above data items 2 and 6 were obtained from the Air Force Engineering and Services Center (AFESC), Tyndall AFB FL, in Defense Energy Information System II (DEIS II) reports. Except as discussed later, complete data was obtained for each item to cover the eight year period from October 1974 through September 1982. Each data item is further described below:

1. Base population. Based on previous research experience, this data were initially requested through major command historians (30:38). It was requested to include all military and civilian personnel normally living or working in base facilities. This would include military and civilian assigned personnel, dependents residing in base housing, and non-appropriated fund (NAF) employees. The following discussions for each base describe the mixed success realized in acquiring the data:

a. Keesler AFB. Yearly population data were obtained for all except the first three months of the analysis period from Headquarters (HQ) Keesler Technical Training Center/HO through HQ Air Training Command (ATC)/HO. The data used in this analysis included all military and civilian personnel assigned to Keesler AFB. Some of the provided data included dependents and NAF employees, but since data for all the years did not include those figures, they were not used in the analysis.

b. Lackland AFB. Monthly population data were obtained for all except the first nine months of the analysis period from the Lackland AFB Historian through HQ ATC/HO. The data included all military and civilian assigned personnel, transient personnel, NAF employees, and dependents residing on the base.

c. Air Force Academy. Yearly population data were obtained for all except the first three months and last

21 months of the analysis period from the Public Relations department at the Air Force Academy. The data included only assigned military personnel, since no reliable civilian data were available.

d. Charleston, McGuire, and Scott AFB's. Yearly population data were obtained for the entire analysis period from HQ Military Airlift Command (MAC)/HO. The data included only military and civilian assigned personnel, since accurate NAF and dependent data were not available.

e. McClellan and Kelly AFB's. Monthly population data were obtained for all except the first 22 months (23 for Kelly) of the analysis period from HQ Air Force Logistics Command (AFLC)/MPKP. The data included only military and civilian assigned personnel, since NAF and dependent data were not available.

f. Offutt and Ellsworth AFB's. Quarterly population data were obtained for all except the first 19 months (22 for Ellsworth) of the analysis period from HQ Strategic Air Command (SAC)/ACMI. The data included all military and civilian assigned personnel, NAF employees, and dependents residing on base.

g. Langley AFB. Quarterly population data were obtained for all except the first three months and the last 13 months of the analysis period from HQ Tactical Airlift Command (TAC)/HO. The data included only military and civilian assigned personnel, since NAF and dependent data were

not available. Partial data were supplied for the last 13 months, but since it did not include personnel assigned to tenant units, that data was not utilized in the analysis.

h. Mountain Home AFB. Quarterly population data were obtained for all except the first three months of the analysis period from HQ TAC/HO. The data included only military and civilian assigned personnel, since NAF and dependent data were not available.

2. Facility square footage. This data includes the square foot floor area for all base facilities that are served by a heating, ventilating, or air conditioning system. The DEIS II reports provided this data for all the bases. However, McClellan and Kelly AFB's, being Air Logistics Centers, had different energy consuming characteristics from those of the other ten bases. Those two bases included significant amounts of square footage occupied by activities consuming primarily "process" energy. This is in contrast to most bases which use primarily "facility" energy that supports such systems as heating, ventilating, air conditioning, and lighting. Square footage data for those two bases was subsequently obtained from HQ AFLC/DEMC, which included only that area occupied by activities consuming primarily "facility" energy.

3. Heating degree days. The number of heating degree days for one calendar day is the number of degrees Fahrenheit (°F) by which the average daily temperature is

less than the base of 65°F (28:iv). This weather data were obtained from USAF/Air Weather Service/Environmental Technical Applications Center through the coordination of AFESC/WE.

4. Cooling degree days. The number of cooling degree days for one calendar day is the number of °F by which the average daily temperature exceeds the base of 65°F (28:iv). The source of the data is the same as that for the heating degree days.

5. Energy factors. AFESC provided ECIP energy project listings for each base, which included dollar costs and completion dates related to each project. Also, most Base or Major Command Civil Engineering organizations provided all known energy projects with their respective costs and completion dates. Only completed projects were included in the analysis. The accuracy of the data for this variable is somewhat less dependable than the data for those preceding.

The number of Operation and Maintenance (O&M) projects that actually have been accomplished is probably much greater than those that were obtained for this study. Most of the major commands and local bases had little information on O&M energy projects before FY 1979. Whatever project filing system they utilized, most only go back to 1979. Also, most filing systems had no special designation for their O&M energy projects, so entire project files would have to be searched to compile these energy projects. Projects could be easily overlooked in this type of search. Another point

that the major commands and local bases admit is that the dollar costs and completion dates could be in error because their files are not always correctly updated with change orders. Another question is that some of the completion dates and final costs on ECIP projects given by AFESC are different than the ones that the local bases stated. The information provided by the local bases will be used instead of the information provided by AFESC if there is a disagreement between the two sources. Each base will now be addressed separately to show the individual situations.

a. Keesler AFB. O&M energy project information was obtained from the base through 3380 Civil Engineering Squadron (CES)/DEM. They had projects that went from December 1976 to May 1982. They included two ECIP projects which AFESC did not have.

b. Lackland AFB. Base and Major Command personnel failed to respond concerning O&M energy projects.

c. Air Force Academy (AFA). O&M energy project information was obtained from the base through AFA/DEM. They had energy project completion dates from 1977 to 1982. They supplied a copy of their Ten Year Facility Energy Plan which included project cost and year completed, but not the completion month. Since the completion months were unknown, the energy projects were simply listed as being completed in the middle of the fiscal year, to provide consistency.

d. Charleston AFB. O&M energy project information was obtained from the base through 437 Air Base Wing (ABW)/DE. HQ MAC/DEE also sent additional information on ECIP project costs and completion dates. There were energy projects with completion dates from December 1974 to April 1982. There were no significant differences in the data from the two sources.

e. McGuire AFB. No listing of O&M energy projects was sent from the base or HQ MAC. Additional information from HQ MAC on ECIP energy projects was very similar to the information from AFESC.

f. Scott AFB. O&M and ECIP energy projects information was obtained from HQ MAC/DEE. There were data for projects which were completed from January 1979 to September 1981. The HQ MAC information on ECIP energy project completion dates differed with AFESC completion dates.

g. McClellan AFB. O&M energy project information was obtained from HQ AFLC/DEE. They included energy project completion dates from FY 1979 to FY 1981 but no completion months. Since the completion months were unknown, the energy projects were simply listed as being completed in the middle of the fiscal year, to provide consistency. The 2852 CES/DE sent additional information on ECIP energy projects which agreed with the information from AFESC.

h. Kelly AFB. O&M energy project information was obtained from HQ AFLC/DEE. They included energy project

completion dates from FY 1979 to FY 1981 but no completion months. Since the completion months were unknown, the energy projects were simply listed as being completed in the middle of the fiscal year, to provide consistency.

i. Langley AFB. O&M and ECIP energy project information was obtained from HQ TAC/DEMU. They had energy project completion dates from October 1978 to June 1979. Their information on ECIP energy projects differed from AFESC's information.

j. Mountain Home AFB. O&M and ECIP energy project information was obtained from HQ TAC/DEMU and from the base through 366 CSG/DEEE. They had energy project completion dates from October 1974 to June 1982. The base information of O&M and ECIP energy projects did not have dollar costs from October 1974 to November 1978, so this information could not be utilized in this analysis. HQ TAC's information had energy project completion dates from November 1977 to July 1982. The HQ TAC information on ECIP energy projects differed with AFESC's information.

k. Offutt AFB. O&M energy project information was obtained from HQ SAC/DEMU. They had energy project completion dates from February 1982 to August 1982. HQ SAC supplied copies of their current project files which included only projects from 1979 to the present.

l. Ellsworth AFB. O&M energy project information was obtained from HQ SAC/DEMU. They had energy

completion dates from November 1981 to August 1982. HQ SAC supplied copies of their current project files which included only projects from 1979 to the present.

6. Energy consumption. This data includes energy consumed in facilities (including base housing units) by month and does not include vehicle or aircraft operations energy consumption. The data was obtained from DEIS II reports. However, as in #2 above, McClellan and Kelly AFB's had different energy consuming characteristics from those of the other ten bases. The total energy consumptions of those two bases included significant amounts of "process" energy for the areas identified in #2 above. This process energy data was obtained from HQ AFLC/DEMC. The data was provided only on a yearly basis, so those amounts had to be divided by 12 before being subtracted from the monthly DEIS II data. Since the process energy consumption should not be dependent on the weather variables (HD and CD), seasonal variations should not be significant in the process energy data. Subtraction of the process energy figures which remain relatively constant for 12-month periods should therefore provide the most accurate facility-energy-consumption estimates possible with the available data.

Research Question and Hypothesis Methodology

As discussed earlier regarding Tinsley's (25) and Weck's (30) research, Multiple Linear Regression (MLR) was

employed in the present study to build energy consumption models. The first five data items listed above are the independent variables used to explain the variation in the final item, energy consumption, which is the dependent variable.

Question 1 is restated here with further clarification. What statistical model will best predict energy consumption as a function of energy requirement variables and moderating variables which account for other energy improvements? A specific model was developed for each control and test base using both independent and dependent variable data as inputs to the stepwise MLR procedure of SPSS. For the control bases, the data for the first half of the eight year data period was used to generate the MLR model coefficients. For the test bases the data prior to the EMCS operational date was used to build the model. The energy factors were all grouped into one variable, with the dollar amounts used as the common attribute in combining them. The energy project documentations included estimates of energy savings factors. An attempt was made to use these to convert all the projects into units of energy. However, the regression analysis was not improved over that using only dollar amounts. Also, based on the authors' experience, these estimated energy savings numbers would probably not be as reliable as the actual dollars spent on a project.

Hypothesis 1 is restated here in null hypothesis (H_o) and alternative hypothesis (H_A) forms: H_{o1}: Energy

consumption predicted by the Question-1 model for non-EMCS (control) installations is equal to actual energy consumption; H_{A1}: Energy consumption predicted by the Question-1 model does not equal actual energy consumption. The null hypothesis was tested by applying the Question-1 model for each control base to the independent variable data for the last half of the data period. The monthly energy consumptions predicted by that model were then statistically compared to the actual monthly energy consumptions for that period, using a two-tailed T-test. The two-tailed T-test was employed here because H_{o1} was to be rejected if a significant deviation was found in either direction. The Question-1 MLR modeling format would be validated for further use in Hypothesis 2 by a statistical "failure to reject" H_{o1} in this T-test.

Hypothesis 2 is restated here in null and alternative hypothesis forms: H_{o2}: Energy consumption predicted by the Question-1 model (excluding EMCS effects) for EMCS (test) installations is equal to actual energy consumption (which includes EMCS effects); H_{A2}: Energy consumption predicted by the Question-1 model (excluding EMCS effects) is greater than actual energy consumption (including EMCS effects). The null hypothesis was tested by applying the model for each test base to the independent variable data for the period after the EMCS operational date. The monthly energy consumptions predicted by that model were then statistically

compared to the actual monthly energy consumptions for that period, using a one-tailed T-test. The one-tailed T-test was employed here because a t-value deviation in one direction only was relevant in rejecting H_{o2} and accepting H_{A2}. If the predicted energy was less than or equal to the actual energy consumption then H_{o2} was not rejected, showing no energy savings occurred. Any energy savings, from the EMCS or for other reasons, would cause the predicted consumptions to exceed the actual consumptions. If the predicted consumptions are greater than the actual consumptions by a statistically significant amount, then H_{o2} is rejected and H_{A2} is accepted. This acceptance of H_{A2} implies the EMCS saves energy. The difference between the predicted and actual energy consumption computed at the 0.1 significance level was the minimum amount of energy saved. Actual energy savings, however, could have been greater than this amount.

Critical region. A 0.1 significance level was used in the MLR model building and in the T-test hypothesis testing. As discussed later, other considerations were also used for the selection of variables in the MLR model.

Assumptions

1. Base population, facility square footage, and energy consumption data reflect correctly the quantities described earlier.

2. Energy consumption data reflects energy consumed only in the buildings included in the facility square footage.

3. Energy factor data reflects correctly the actual dollars spent on all energy projects other than EMCS.

4. T-test assumption. The only assumption required for use of the matched-pairs T-test is that the energy consumption values be normally distributed. This assumption is not critical, by virtue of the Central Limit Theorem, since all the bases except Keesler and Kelly have more than 30 monthly data points (16:273-275). Keesler has only 17 months for the T-test and Kelly has only 24 months, so the assumption is more critical for these two bases.

Limitation

An area not specifically analyzed in this study is the contribution to energy waste of improperly operated, maintained, or calibrated control equipment. The energy consumption data utilized in this project includes the effects of any faulty calibration or operation of both EMCS and non-EMCS control systems. This is not considered a significant limitation since these operational conditions are assumed to affect EMCS and non-EMCS systems equally.

Multiple Linear Regression

MLR was selected for this study because Tinsley (25:93,96) judged MLR the best statistical model of energy consumption. Also, Weck's (30:63) research supported the use of MLR in this area. Several MLR characteristics make it the appropriate tool for this analysis. The objective

of regression analysis is to describe the nature of the relationship between two or more variables. An appropriate use of MLR is to predict or estimate the value of one dependent variable based on known values of two or more independent variables.

The prediction is accomplished in two basic steps. The first analyzes, for a group of data in a development period, the relationship between actual values of the dependent variable and actual values of the independent variables. A linear function of the form $Y = A + B_1X_1 + B_2X_2 + \ldots + B_nX_n$ will be developed with the least-squares curve fitting method. In this method a deviation is measured between each actual Y value and the value of the right side of the equation based on the corresponding $X_1 \ldots X_n$ values. The A and B coefficients are set to minimize the sum of the squares of each of these deviations.

The Statistical Package for the Social Sciences (SPSS) Stepwise Regression procedure was used to develop the model (20:320-367). It judges the contribution of each eligible independent variable toward minimizing the squared deviation errors in the final model. The following five factors should exhibit certain characteristics as each additional independent variable improves the model. These factors were the primary criteria for selecting the independent variables to be included in the final model for each base:

1. The mean square error (MSE) measures the average squared deviation. This is also known as the variation of

Y that is not explained by the regression model. The model is improved if the MSE decreases with the addition of another independent variable.

2. The coefficient of determination, R-Squared, measures with a value between zero and one the proportion of the total variation in Y that is explained by the regression model. This is inversely related to the MSE, and will increase with the addition of a contributing independent variable. The size of this increase is an indicator of the contribution value of the independent variable.

3. A more comprehensive variation of the R-Squared is the Adjusted R-Squared, which considers changes in the statistical degree-of-freedom. Thus, the contribution value of the entering independent variable must more than offset the adverse degree of freedom effect to produce an increase in the Adjusted R-Squared.

4. Another related statistic is the F-test, which measures the ratio of the explained variation to the unexplained variation. Because of changes in the statistical degrees of freedom of the F-statistic, it may decrease with the addition of independent variables. However, it should remain large enough to have a statistical significance level considerably less than 0.1. A significant F-statistic rejects the null hypothesis that all the B coefficients equal zero (H_O: B=0) and accepts the alternative hypothesis (H_A) that at least one B coefficient does not equal zero.

5. Incremental F-statistics are also computed for each independent variable. If they are significant at the 0.1 level, then H_O: B=0 is rejected and H_A: B≠0 is accepted for each B coefficient. This occurrence would mean that these independent variables are statistically valid elements of the regression model.

The second step involves employing the model on a group of data in a testing period to predict or estimate values of the dependent variable. The A and B coefficients are those set in the development period analysis. The $X_1 \ldots X_n$ independent variable values are those of the testing period data.

The eight primary assumptions required for applying the MLR model are described below. They must hold true if the model is to be valid in explaining the variations of the dependent variable.

1. Similar Ranges of Data in the Control and Test Periods. For the independent variables included in the model, the values in the test group data should fall within the range of values in the control group data for the model to be valid in both groups.

2. Linearity. An approximately linear relationship must exist between the dependent variable and the combination of independent variables. Since simple two-way scattergram comparisons do not adequately describe a model with multiple independent variables, another criteria must be used. The R-Squared values indicate a strong linear

relationship if they are significantly large; for example, higher than 0.6

3. Constant Variance. The distribution of the residual terms should have a constant variance (homoscedasticity). Scattergrams were plotted of the predicted values of the dependent variable against the deviations (residuals) between the predicted and actual dependent variable values. The sizes of the residuals should present a stable appearance with no evident trends.

4. Independence of Residual Terms. The residual terms should be independent of each other, which means that no autocorrelation exists and that their covariance equals zero. This assumption is satisfied if the Durbin-Watson statistic calculated by SPSS falls within a desirable range as outlined in Harnett (16:566-570,p.A-54).

5. Normally Distributed Residuals. The residuals should be normally distributed. This is verified by an approximately normal distribution appearance of the SPSS plot of residuals.

6. All Important Variables Included. All important independent variables should be included in the model. This is substantiated by significantly large coefficients of determination (R-Squared). This means that a significantly large proportion of variation in the dependent variable is explained by the regression model.

7. Few Outliers from the Regression Model. The regression model should fit all observations with few outliers. This means that the number of large residuals should not be significantly different from that expected from a normal distribution. For instance, approximately 5% of the observations should fall outside two standard deviations. This assumption can be verified by inspection of either a list or plot of the residuals.

8. No Linear Relationships Between Independent Variables. No independent variable should be a linear combination of any other independent variable, which would be multicollinearity. This can be verified in two ways. First, the absolute value of the correlation coefficients (R) for each pair combination of independent variables should be small (approximately 0.2 or less). Second, the B coefficient values should remain relatively stable throughout the regression steps, also indicating insignificant multicollinearity between the independent variables (7; 16:546-571).

CHAPTER 3

RESULTS

Introduction

The first objective of this thesis was to develop for each of the 12 bases a statistical model which predicts energy consumption for that base. This was accomplished by applying Multiple Linear Regression (MLR) to the independent and dependent variable data in the control portion of the eight-year analysis period. The important independent variables for the final models were chosen by their performance in relation to the five selection-criteria factors described in Chapter 2. Some additional subjective criteria will be discussed in this chapter.

The second and third objectives were to test whether the energy predicted by the above model equaled or exceeded the actual energy consumption during the test period at each base. For the four control bases, the MLR model was validated if the predicted energy consumptions equaled the actual energy consumptions (within a statistical confidence interval). For the eight test (EMCS) bases, an energy savings was confirmed and quantified if the predicted energy was greater than the actual energy consumption by a statistically significant amount. These objectives were achieved by applying the developed MLR models to the independent

variable data in the test portion of the analysis period. The resulting predicted dependent variable values were then compared with the actual values by using the matched-pairs T-test. The results of these T-tests were sometimes quite sensitive to the selection of variables in the MLR models. This sensitivity, in addition to some special problems related to individual bases, necessitated a separate analysis for each base. The regression assumptions will also be addressed in each base's discussion. The following analysis will begin with discussion of some general results and assumptions, and then proceed with the base-by-base analysis.

ANALYSIS

General Results

The terms "control period", "test period", and "eight-year period" are used frequently in this analysis, and are defined in the following three paragraphs.

The eight-year period is the total period analyzed in this study, which corresponded to the availability of data in the DEIS II reports. The eight-year period included October 1974 through September 1982, which also comprises the fiscal years of 1975 through 1982.

The control period has different meaning for the control (non-EMCS) bases and test (EMCS) bases. For the control bases it is simply the first half of the eight-year period, which is October 1974 through September 1978. The

control period varies, however, for each of the test bases because it includes the time period from October 1974 to the month when the EMCS was first considered operational. The exact control periods are listed later in the analyses for each base.

The test period also has different meaning for the control bases and test bases. For the control bases it is the second half of the eight-year period, which is October 1978 through September 1982. The test period varies, however, for each of the test bases because it includes the time period from when the EMCS was first considered operational through September 1982. The exact test periods are listed later in the analyses for each base.

In addition to the five selection-criteria factors discussed in Chapter 2, additional methods were necessary to select the independent variables that would provide valid, consistent results in the regression and T-test analyses. One method for evaluating this consistency is described in the rest of this paragraph. For all the variables that exhibited statistical significance in the control period, the regression and T-test analyses that utilized all of them sometimes produced very erratic results. When this occurred the data file was visually examined for irregularities in the data for one or more of the variables. A variable related to irregular data could then be removed from the MLR model, and the analysis reaccomplished to obtain a valid result.

Another useful variable-selection method was to run a regression on the entire eight-year period. Since the control-period model was assumed to also be relevant for the rest (test portion) of the eight-year period, the variables in the model should show some consistency when applied over both periods. This did appear to be the case. The variables that showed some similarity in their B coefficients and significance levels between the control-period regression and eight-year regression produced the most believable results in the test-period T-tests.

In this analysis, the term "B coefficient" refers to the coefficients of the independent variables in the regression equation (MLR model) as in the following example: $Y = A + B_1{*}HD + B_2{*}CD$. The A in this equation is also referred to as the constant in the MLR model. The term "significance levels" refers to the statistical significance of the B coefficients of the independent variables, as computed by SPSS in the MLR model development. As discussed in the "Critical region" paragraph of Chapter 2, the significance level of a B coefficient must be less than 0.1 to allow its related independent variable to be included in a final MLR model for this study.

Each of the five possible independent variables exhibited significance in the MLR model for at least one of the bases. Heating degree days (HD) was a significant variable in all the models. Cooling degree days (CD) was

significant in eight of the 12 models. These two exhibited the most significance and consistency overall. The other three, facility square footage (AREA), population (POP), and the dollar value of energy projects (DPRJ), were involved in one, two, and three of the final models, respectively. These three variables were also involved in some of the borderline models considered, which often produced different T-test results from the finally selected models. A sixth variable, the energy value of the energy projects (EPRJ), was tested in the MLR model development. When it was employed in place of DPRJ, EPRJ usually produced similar results to those of DPRJ. However, for the reasons expressed in Chapter 2, EPRJ was not utilized in the final models.

In an effort to consider all possible relationships between the dependent variable (energy consumption), the independent variables discussed above, and the effect of an operational EMCS, a dummy variable was utilized for the eight EMCS bases. The role of the dummy variable in regression analysis is described in Appendix C. The application of the dummy variable in this study is also further explained in the base-by-base analysis later in this chapter. The dummy variable, PD, was set to zero during the control period (before the EMCS was operational) and to one during the test period (after the EMCS became operational). This would have the effect of changing the constant in the MLR

model when EMCS came into operation. Further, PD was employed in crossproducts with the other independent variables to see if it would affect the B coefficient relationships (slopes) of the MLR model. The dummy variable and its crossproducts were then employed in regression runs over the entire eight-year period. There appeared to be significant effects on a few bases, which will be discussed later. The regression analysis on the remaining bases showed no significant contributions from the dummy variable or its crossproducts.

Assumptions

The eight regression assumptions listed in Chapter 2 will be addressed here where the results can be generalized for all the bases. Where necessary, further detail will be included in the base-by-base analysis. The subparagraph numbers below correspond to the numbers by which the assumptions are listed in Chapter 2.

1. Similar Ranges of Data in the Control and Test Periods. The values of HD and CD cycle seasonally, so the ranges of values are very similar for the control and test periods. The AREA values for the test period were within the range of control-period values for the base where AREA was a significant independent variable. However, the POP and DPRJ values did not always maintain their range between the periods. The DPRJ, especially, was sometimes much higher at the end of the test period than at any time during the

control period. As discussed later, a few of the bases with POP or DPRJ in their MLR model cannot satisfy this assumption.

2. Linearity. Nine of the 12 bases had Adjusted R-Squared values above 0.8 in their MLR models. The other three had values above 0.6. This indicates that approximately linear relationships generally exist between the dependent variable and the combinations of independent variables for this MLR modeling format.

3. Constant Variance. The scattergram plots of residuals showed a reasonably stable appearance for all bases, thus satisfying this assumption.

4. Independence of Residual Terms. Two bases, Keesler and Kelly, exhibited some significant autocorrelation, while three others, Charleston, McGuire, and Scott, showed possibilities of weak autocorrelation. This will be addressed further in those bases' discussions.

5. Normally Distributed Residuals. The residual plots showed approximately normal distribution for all the bases, thus satisfying this assumption.

6. All Important Variables Included. As discussed for assumption 2 above, all bases showed that a significant proportion of variation in the dependent variable, energy consumption (NRGY), was explained by the MLR model.

7. Few Outliers from the Regression Model. Ten of the 12 bases had 5% or fewer observations outside two standard deviations (outliers), while two had more than 5% outliers.

The lowest value was 2.44% based on one out of 41 observations, while the highest was 8.06% based on five out of 62 observations. These deviations from 5% are not unreasonable considering the relatively small number of data points for each base. Thus the assumption can be considered satisfied for all bases (31).

8. No Linear Relationships Between Independent Variables. Both HD and CD were included as independent variables for eight of the 12 bases. In the other four bases, HD was a significant independent variable while CD was not significant and was not included in the MLR model. For each of those former eight bases, the correlation coefficient for this variable pair was about -0.7, which indicates significant multicollinearity between HD and CD. Also, when the second of these variables entered the regression model, the B coefficient for the first variable increased significantly. The increase ranged from 14% to 154% over the eight bases. As mentioned previously in the background literature review, Weck (30:64) concluded that this multicollinearity should not significantly degrade the overall regression models because high values of HD and CD usually do not occur simultaneously. In the present analysis, the MLR models do seem to produce good predictions with the HD and CD variables included together. There was no significant multicollinearity between any other variable combinations for the 12 bases.

In summary, the regression assumptions were generally well satisfied in this study. The few individual problems

related to assumptions 1 and 4 will be discussed later, along with the impact on the results, in the base-by-base analysis. This success, along with the previously discussed conclusions from Tinsley's (25) and Weck's (30) research, confirm the selection of MLR as the appropriate energy prediction model for this study.

Tabulated Regression Results

The following two tables summarize the regression and T-test results of this study. Table 3-1 lists the results of the regression performed on the control period data for each base. Also listed are the results of the T-tests performed on the test period data, with the percentages of energy savings where applicable. The column headed by Constant lists the value of the constant A in each base's final MLR model. The columns headed by HD through AREA list the values of the B coefficients of the variables that are included in each base's final MLR model. A dash is shown where a variable was statistically insignificant and not included in the MLR model. The numbers in parenthesis below the value of each constant and B coefficient indicate the significant level of those values. As discussed earlier, this significance level had to be less than 0.1 for the related variable to be included in the final MLR model. The Adj R-Sq column lists the Adjusted R-Squared values for each base's MLR model. These values, which are all greater

than 0.6, indicate the proportion of the variation in the independent variable which is explained by each base's MLR model.

The t column lists the t value computed by the T-test between the predicted and actual energy values in the test period. Positive t values indicate the average predicted energy consumption was greater than the average actual energy consumption. The Signif. column lists the significance of the t values in the T-tests. As discussed earlier, a significance less than 0.1 indicated H_o should be rejected, while a significance greater than 0.1 indicated H_o could not be rejected. As indicated in the table, the significance was computed in a one-tailed test for the test bases (#1-8) and in a two-tailed test for the control bases (#9-12). The percentage of energy savings was listed for the four test bases that exhibited significant energy savings. The percentage means, with 90% certainty, there was an average energy savings of at least the listed percentage, that was not explained by the MLR model. The complete energy savings computations are included later in the base-by-base analysis.

Table 3-2 lists the results of the regression performed on the entire eight-year period data for each base. These regressions were performed to investigate dummy variable effects and to examine similarity in the B coefficients between the control period MLR models and the eight-year period regression results. The columns headed by Constant,

Adj R-Sq, and HD through AREA list the same type of information as in Table 3-1. Three other columns were headed by the dummy variable PD, and dummy crossproduct variables PDHD and PDCD. Those columns list the related B coefficients and significance levels, just as in the columns for the other variables.

<u>Keesler AFB</u>

For this test base, the control period was October 1974 through April 1981, with the test period being May 1981 through September 1982.

HD, CD, and DPRJ were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 173484.486 + 114.612*HD + 147.013*CD - 0.018*DPRJ. All the regression assumptions were satisfied except the first one regarding similar ranges of data in the control and test periods, and the fourth one regarding autocorrelation. Regarding the first one, the value of DPRJ increased by the end of the test period to 1.4 times its value at the end of the control period. However, its B coefficient in the control-period model had a significance of 0.089, with a value consistent with the corresponding value in the eight-year regression run. Therefore, DPRJ was retained in the model.

Regarding the fourth assumption, the Durbin-Watson (D-W) test showed that significant positive autocorrelation exists in the regression. This means the residual terms

TABLE 3-1

REGRESSION CONSTANTS AND COEFFICIENTS WITH T-TEST RESULTS

Base #	Base Name	Constant	HD Heating Degree Days	CD Cooling Degree Days	POP Base Population	DPRJ Dollar Energy Projects	AREA	Adj R-Sq	T-test 1-8:1-tail 9-12:2-tail t	Signif.	% Energy Savings
1	Keesler AFB	173484 (0)	115 (0)	147 (0)	-	-.018 (.089)	-	.616	.08	.468	-
2	Lackland AFB	139862 (0)	144 (0)	181 (0)	-	-	-	.664	1.89	.034	.84
3	Charleston AFB	-98256 (.004)	88.8 (0)	85.7 (0)	27.4 (0)	-	-	.812	.52	.303	-
4	McClellan AFB	264966 (0)	177 (0)	-	-	-	-.010 (.028)	.934	.09	.464	-
5	McGuire AFB	79953 (0)	136 (0)	81.6 (.01)	-	-	-	.915	2.90	.003	1.8
6	[illegible] AFB	73305 (0)	78.3 (0)	115 (0)	2.36 (.053)	-	-	.889	2.50	.009	1.3
7	Air Force Academy	132718 (0)	85.2 (0)	-	-	-.007 (.010)	-	.812	-.44	.332	-
8	Offutt AFB	153578 (0)	107 (0)	210 (0)	-	.058 (.014)	-	.914	2.70	.005	1.4
9	Kelly AFB	160451 (0)	210 (0)	117 (0)	-	-	-	.615	-2.59	.016	
10	Langley AFB	97456 (0)	149 (0)	122 (0)	-	-	-	.842	.91	.367	
11	Mountain Home AFB	64970 (0)	57.5 (0)	-	-	-	-	.903	1.67	.102	
12	Ellsworth AFB	94225 (0)	103 (0)	-	-	-	-	.980	4.99	0	

NOTE: Numbers in parentheses indicate the significance of each coefficient.

TABLE 3-2

EIGHT-YEAR REGRESSION CONSTANTS AND COEFFICIENTS

Base #	Base Name	Constant	HD Heating Degree Days	CD Cooling Degree Days	POP Base Population	DPRJ Dollar Energy Projects	AREA	PD Period Before/After EMCS	PDHD Cross Product PD X HD	PDCD Cross Product PD X CD	Adj R-Sq
1	Keesler AFB	171340 (0)	117 (0)	153 (0)	-	-.014 (.070)	-	-	-58.5 (.056)	-	.664
2	Lackland AFB	-86545 (.252)	142 (0)	170 (0)	3.81 (.004)	-	.012 (.037)	-	-	-32.5 (.034)	.686
3	Charleston AFB	-36579 (.083)	107 (0)	102 (0)	15.9 (0)	-	-	-	16.9 (.014)	-37.7 (0)	.861
4	McClellan AFB	277176 (0)	179 (0)	-	-	-	-.011 (.056)	-	-27.0 (.027)	53.8 (.001)	.838
5	McGuire AFB	81685 (0)	128 (0)	67.4 (0)	-	-	-	-	-	-	.928
6	Scott AFB	73609 (0)	78.9 (0)	115 (0)	2.41 (.038)	-	-	-3701 (.128)	-	-	.882
7	Air Force Academy	132162 (0)	86.3 (0)	-	-	-.007 (0)	-	-	-	-	.855
8	Offutt AFB	148335 (0)	35 (0)	224 (0)	-	.036 (.014)	-	-	-	-	.884
9	Kelly AFB	164536 (0)	189 (0)	133 (0)	-	-	-				.515
10	Langley AFB	99605 (0)	143 (0)	109 (0)	-	-	-				.782
11	Mountain Home AFB	64713 (0)	56.0 (0)	-	-	-	-				.888
12	Ellsworth AFB	91987 (0)	98.5 (0)	-	-	-	-				.949

NOTE: Numbers in parentheses indicate the significance of each coefficient.

are not independent of each other, thereby diluting the meaning of the regression results.

The T-test performed to test Hypothesis 2 produced a $t = 0.08$ with a significance of 0.468. This failed to reject H_{o2}, indicating that no energy savings occurred that was not explained by the MLR model. The lack of conclusive verification of the normality assumption for Keesler's data is somewhat critical because only 17 observations were available for this T-test. These results, as well as the autocorrelation problem, all contribute to the conclusion that H_{o2} cannot be rejected in order to accept H_{A2} for this base.

Another factor, however, does indicate some energy savings occurred during the test (latter) portion of the eight-year period. In the eight-year regression run, the B coefficient for the PDHD dummy-variable crossproduct was -58.490. The negativity indicates that when PD equals one (after EMCS became operational), an increase in HD will cause a lesser increase in predicted energy consumption than when PD equals zero. However, over the range of HD values observed, this lesser increase in predicted energy was not sizeable enough to cause a statistically significant difference in the T-test on the test period data. Thus, the T-test result provides the most direct answer to the hypothesis in question (31).

Lackland AFB

For this test base, the control period was October 1974 through April 1979, with the test period being May 1979 through September 1982.

HD and CD were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 139862.474 + 144.206*HD + 181.386*CD. All the regression assumptions were satisfied by this model.

The T-test performed to test Hypothesis 2 produced a t = 1.89 with a significance of 0.034. This rejected H_{o2} and accepted H_{A2}, indicating an energy savings occurred that was not explained by the MLR model. To compute the actual amount of energy saved, the following T-test manipulation was performed:

$$P((D-\Delta)/SE \leq t_{40,0.1}) = 0.90$$

where P = Probability,

D = mean difference from SPSS T-test,

Δ = energy savings to be calculated,

SE = standard error from SPSS T-test,

t = critical value from t-distribution table (16:p.A-49),

40 = degrees of freedom, or the number of cases minus one,

0.1 = significance level,

0.90 = confidence interval.

Rearranging terms:

$$P(\Delta \geq D - SE{*}t_{40,0.1}) = 0.90$$

$P(\Delta \geq 5538.6724 - 2936.35*1.303) = 0.90$

$P(\Delta \geq 1713) = 0.90$

This means, with 90% certainty, there was an average monthly savings of at least 1713 MBTU's that was not explained or predicted by the MLR model. This savings is for the test period (after the EMCS operational date) as compared to the control period (before the EMCS operational date). The savings can be converted to a percentage by multiplying by 100 and dividing by the average monthly energy consumption as follows: 100*1713/203370 = 0.84%.

Another factor also indicated some energy savings occurred during the test (latter) portion of the eight-year period. In the eight-year regression run, the B coefficient for the PDCD dummy-variable crossproduct was -32.507. The negativity indicates that when PD equals one, an increase in CD will cause a lesser increase in predicted energy consumption than when PD equals zero. This dummy-variable effect supports the T-test conclusion that a statistically significant energy savings occurred in the test period.

Charleston AFB

For this test base, the control period was October 1974 through December 1977, with the test period being January 1978 through September 1982.

HD, CD, and POP were the significant independent variables in this base's MLR model. The Question-1 model

is as follows: NRGY = -98256.325 + 88.769*HD + 85.716*CD + 27.425*POP. All the regression assumptions were satisfied except the fourth one regarding autocorrelation and a slight problem with the first one regarding similar ranges of data in the control and test periods.

Regarding the first assumption, the value of POP had only a slightly different range of values in the two periods. Its lowest value in the test period was only slightly less (4%) than its minimum value in the control period. This difference was judged by the researchers to be small enough so the model would still be valid for the range of POP values in the test period.

Regarding the fourth assumption, the Durbin-Watson test was inconclusive since it produced a D-W statistic in the range of possible positive autocorrelation. Although a problem could exist, the inconclusiveness indicates the overall regression results should not be seriously affected (16:567-570).

The T-test performed to test Hypothesis 2 produced a $t = 0.52$ with a significance of 0.303. This failed to reject H_{o2}, indicating that no energy savings occurred that was not explained by the MLR model.

Two other factors, PDHD and PDCD crossproducts, exhibited some interesting effects in the eight-year regression run. The B coefficients were 16.857 for PDHD and -37.664 for PDCD. The different signs mean that when PD

equals one, an increase in HD will cause a greater increase in predicted energy consumption, while an increase in CD will cause a lesser increase in energy. Since the average value of HD is slightly less than the average value of CD, the net effect of the seasonal variations would indicate an overall reduction in predicted energy consumption. This dummy-variable effect is similar to that described in Keesler's analysis above. Since the effect was not sizeable enough to produce a statistically significant t value, the T-test result provides the most direct answer to the hypothesis in question (31).

McClellan AFB

For this test base, the control period was October 1974 through December 1978, with the test period being January 1979 through September 1982.

HD and AREA were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 264966.248 + 176.659*HD - 0.010*AREA. All the regression assumptions were satisfied by this model.

The T-test performed to test Hypothesis 2 produced a $t = 0.09$ with a significance of 0.464. This failed to reject H_{o2}, indicating that no energy savings occurred that was not explained by the MLR model.

Two other factors, PDHD and PDCD crossproducts, exhibited some interesting effects in the eight-year regression run. The B coefficients were -27.039 for PDHD and 53.787

for PDCD. The different signs mean that when PD equals one, an increase in HD will cause a lesser increase in predicted energy consumption, while an increase in CD will cause a greater increase in energy. Since the average value of HD is somewhat less than twice the average value of CD, the seasonal variations in these effects will approximately cancel each other. This result supports the T-test conclusion that no significant energy savings occurred in the test period that was not explained by the MLR model.

McGuire AFB

For this test base, the control period was October 1974 through December 1977, with the test period being January 1978 through September 1982.

HD and CD were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 79952.768 + 136.213*HD + 81.615*CD. All the regression assumptions were satisfied except the fourth one regarding autocorrelation. The Durbin-Watson test was inconclusive since it produced a D-W statistic in the range of possible positive autocorrelation. Although a problem could exist, the inconclusiveness indicates the overall regression results should not be seriously affected (16:567-570).

The T-test performed to test Hypothesis 2 produced a $t = 2.90$ with a significance of 0.003. This rejected H_{o2} and accepted H_{A2}, indicating an energy savings occurred that was not explained by the MLR model. To compute the

actual amount of energy saved, the following T-test manipulation was performed:

$$P((D-\Delta)/SE \leq t_{56,0.1}) = 0.90$$

$$P(\Delta \geq D - SE*t_{56,0.1}) = 0.90$$

$$P(\Delta \geq 4559.2801 - 1574.537*1.2974) = 0.90$$

$$P(\Delta \geq 2516) = 0.90$$

This means, with 90% certainty, there was an average monthly savings of at least 2516 MBTU's that was not explained or predicted by the MLR model. This savings is for the test period (after the EMCS operational date) as compared to the control period (before the EMCS operational date). The savings can be converted to a percentage by multiplying by 100 and dividing by the average monthly energy consumption as follows: 100*2516/139648 = 1.8%.

<u>Scott AFB</u>

For this test base, the control period was October 1974 through February 1980, with the test period being March 1980 through September 1982.

HD, CD, and POP were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 74305.022 + 78.347*HD + 115.072*CD + 2.356*POP. All the regression assumptions were satisfied except the fourth one regarding autocorrelation. The Durbin-Watson test was inconclusive since it produced a D-W statistic in the range of possible negative autocorrelation.

Although a problem could exist, the inconclusiveness indicates the overall regression results should not be seriously affected (16:567-570).

The T-test performed to test Hypothesis 2 produced a $t = 2.50$ with a significance of 0.009. This rejected H_{o2} and accepted H_{A2}, indicating an energy savings occurred that was not explained by the MLR model. To compute the actual amount of energy saved, the following T-test manipulation was performed:

$$P((D-\Delta)/SE \leq t_{30,0.1}) = 0.90$$
$$P(\Delta \geq D - SE*t_{30,0.1}) = 0.90$$
$$P(\Delta \geq 3686.4852 - 1477.201*1.310) = 0.90$$
$$P(\Delta \geq 1751) = 0.90$$

This means, with 90% certainty, there was an average monthly savings of at least 1751 MBTU's that was not explained or predicted by the MLR model. This savings is for the test period (after the EMCS operational date) as compared to the control period (before the EMCS operational date). The savings can be converted to a percentage by multiplying by 100 and dividing by the average monthly energy consumption as follows: 100*1751/136723 = 1.3%.

Another factor also indicated some energy savings occurred during the test portion of the eight-year period. In the eight-year regression run, the B coefficient for the PD dummy variable was -3700.710. The negativity indicates that when PD equals one, for a given set of independent

variable values, the predicted energy consumption will be less than when PD equals zero. This dummy-variable effect supports the T-test conclusion that a statistically significant energy savings occurred in the test period.

Air Force Academy

For this test base, the control period was October 1974 through November 1979, with the test period being December 1979 through September 1982.

HD and DPRJ were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 132748.346 + 85.203*HD - 0.007*DPRJ. All the regression assumptions were satisfied except the first one regarding similar ranges of data in the control and test periods. The value of DPRJ increased in the test period to one-third more than its maximum value during the control period. However, its B coefficient in the control-period model had a significance of 0.01, with a value consistent with the corresponding value in the eight-year regression run. Therefore, DPRJ was retained in the model.

The T-test performed to test Hypothesis 2 produced a t = -0.44 with a significance of 0.332. The negative t value resulted from a slightly negative predicted-actual energy consumption difference. This indicates that no energy saving was experienced that was not explained by the MLR model. The negative energy difference, along with the large

significance, shows that H_{o2} cannot be rejected in order to accept H_{A2} for this base.

Offutt AFB

For this test base, the control period was October 1974 through February 1978, with the test period being March 1978 through September 1982.

HD, CD, and DPRJ were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 153578.077 + 107.051*HD + 209.91*CD + 0.058*DPRJ. All the regression assumptions were satisfied except the first one regarding similar ranges of data in the control and test periods. The value of DPRJ increased at the end of the test period to more than twice its value at the end of the control period. However, its B coefficient in the control-period model had a significance of 0.014, with a value consistent with the corresponding value in the eight-year regression run. Therefore, DPRJ was retained in the model.

The T-test performed to test Hypothesis 2 produced a $t = 2.70$ with a significance of 0.005. This rejected H_{o2} and accepted H_{A2}, indicating an energy savings occurred that was not explained by the MLR model. To compute the actual amount of energy saved, the following T-test manipulation was performed:

$$P((D-\Delta)/SE \leq t_{54,0.1}) = 0.90$$

$$P(\Delta \geq D - SE*t_{54,0.1}) = 0.90$$

$$P(\Delta \geq 6388.6426 - 2368.669*1.2981) = 0.90$$

$$P(\Delta \geq 3314) = 0.90$$

This means, with 90% certainty, there was an average monthly savings of at least 3314 MBTU's that was not explained or predicted by the MLR model. This savings is for the test period (after the EMCS operational date) as compared to the control period (before the EMCS operational date). The savings can be converted to a percentage by multiplying by 100 and dividing by the average monthly energy consumption as follows: 100*3314/233482 = 1.4%.

Kelly AFB

As discussed in Chapter 2, process energy data was obtained for the two AFLC bases and subtracted from the monthly energy consumptions to produce the facility energy data. For Kelly, however, process energy data was available for only the last half of the eight-year period. To use only consistent energy data, that latter four-year period was then divided in half to obtain separate two-year periods as control and test periods. For this control base, then, the control period was October 1978 through September 1980, with the test period being October 1980 through September 1982. Since less than 30 observations were available for the separate regression and T-test operations, meeting the normality assumption becomes somewhat more critical. However, since

the number of available observations (24) is reasonably close to the desired number (30), satisfactory results can still be expected (16:275).

Using this shorter analysis period, HD and CD were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 160451.040 + 210.126*HD + 116.830*CD. All the regression assumptions were satisfied except the fourth one regarding autocorrelation. The Durbin-Watson test showed that some positive autocorrelation existed in the regression. This means the residual terms are probably not independent of each other, thereby diluting the meaning of the regression results.

The T-test performed to test Hypothesis 1 produced a $t = -2.59$ with a significance of 0.016. This rejected H_{o1} and accepted H_{A1}, indicating that the Question-1 model did not adequately explain the actual energy consumption during the test period.

Another unexpected characteristic of Kelly's data was a high correlation between NRGY and HD, with a low correlation between NRGY and CD. Conversely, the data for both of the other bases in climate zone 1 exhibited the highest correlation between NRGY and CD, which is the most logical relationship for those southern bases. This problem, the T-test result, and the autocorrelation problem all support the conclusion that the Question-1 model cannot satisfactorily explain energy consumption for this base.

Langley AFB

For this control base, the control period was October 1974 through September 1978, with the test period being October 1978 through September 1982.

HD and CD were the significant independent variables in this base's MLR model. The Question-1 model is as follows: NRGY = 97456.299 + 149.171*HD + 122.349*CD. All the regression assumptions were satisfied by this model.

The T-test performed to test Hypothesis 1 produced a t = 0.91 with a significance of 0.367. This failed to reject H_{o1}, indicating that the Question-1 model adequately explained the actual energy consumption during the test period.

Mountain Home AFB

For this control base, the control period was October 1974 through September 1978, with the test period being October 1978 through September 1982.

HD was the only significant independent variable in this base's MLR model. The Question-1 model is as follows: NRGY = 64969.842 + 57.489*HD. All the regression assumptions were satisfied by this model.

The T-test performed to test Hypothesis 1 produced a t = 1.67 with a significance of 0.102. This failed to reject H_{o1}, indicating that the Question-1 model adequately explained the actual energy consumption during the test period.

Ellsworth AFB

For this control base, the control period was October 1974 through September 1978, with the test period being October 1978 through September 1982.

HD was the only significant independent variable in this base's MLR model. The Question-1 model is as follows: NRGY = 94224.951 + 102.593*HD. All the regression assumptions were satisfied by this model.

The T-test performed to test Hypothesis 1 produced a t = 4.99 with a significance of 0.0. This rejected H_{o1} and accepted H_{A1}, indicating that the Question-1 model did not adequately explain the actual energy consumption during the test period.

CHAPTER 4

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

The goal of this research effort was to determine if energy was being saved through the operation of Energy Management Control Systems installed throughout the Air Force. This request for EMCS verification came from HQ USAF/LEEEU. Congressional staff members have demanded proof that shows that the Air Force is saving energy through EMCS.

Several problems were discovered in the search for a method to verify savings. The problems are: (1) historical energy consumption data for buildings is not available; (2) isolating the effects of EMCS is difficult because many other energy projects have been accomplished during the time of EMCS operation; (3) the installation of EMCS altered the standard operation of most HVAC equipment so the actual improvements cannot be measured by simply turning off an EMCS; and (4) comparing one year's energy consumption with another is meaningless because the total heating/cooling degree days can vary as much as 50% from one year to the next.

There were only 18 bases that had an operational system at the time of this writing. Because of both limited time for the analysis, and a desire for a representative sample of EMCS's that had been operating for a reasonable time,

decision criteria were developed for rigorous selection of the bases. The EMCS bases were selected according to the following rules: (1) only two bases per heating zone were selected; (2) energy consumption data had to be available two years before EMCS operation and two years after EMCS operation; and (3) the EMCS at each base had to have at least 500 monitor and/or control points. The control bases (non-EMCS) were selected according to the following criteria: (1) one base was selected for each of the winter heating zones that had two EMCS bases that met the above criteria; and (2) energy consumption data had to be available for at least the last four years. The EMCS bases selected were Keesler and Lackland for heating zone one, Charleston and McClellan for heating zone two, McGuire and Scott for heating zone three, and the Air Force Academy and Offutt for heating zone four. There were no EMCS bases for heating zones five and six. The control bases selected were Kelly for heating zone one, Langley for heating zone two, Mountain Home for heating zone three and Ellsworth for heating zone four.

Data for these bases were received from various sources. The Air Force Engineering and Service Center (AFESC) provided the weather data, the ECIP energy projects and base facility square footage. The base or its respective major command provided the data on base population and energy projects other than ECIP. All the data for the EMCS and control bases were analyzed with the SPSS Regression program.

One research question and two hypotheses were developed to analyze the EMCS verification. The question is what statistical model will predict the energy consumption with the given variables. The first hypothesis is whether the predicted energy consumption matched the actual energy consumption for non-EMCS bases. The second hypothesis is that the predicted energy consumption is greater than actual energy consumption for EMCS bases.

Conclusions

Question 1. The literature review revealed that multiple linear regression (MLR) can provide accurate predictions of energy consumption. The variables used in previous MLR energy consumption prediction studies were heating degree days, facility square footage and base population. This study added another variable to account for the effects of energy projects other than EMCS. The measurement unit of this variable was dollars spent on these energy projects.

Resolution of Question 1. MLR was found to be the most appropriate statistical model for this study. The most significant variables in descending order of importance were HD, CD, POP, DPRJ, and AREA.

Hypothesis 1. The aim for the control bases was that the predicted value compared to the actual value would be insignificant or have a significance greater than 0.10 (no significant difference) using the paired t-test. For the control bases the predicted energy consumption of

Langley and Mountain Home were not significantly different from the actual energy consumption. For the control bases of Kelly and Ellsworth the predicted value was significantly different from the actual energy consumption. Upon further examination of these bases, possible reasons for these were discovered. Kelly, like McClellan, is an Air Logistics Center with considerable maintenance process energy consumption. As with McClellan, the process energy portion has increased consistently during the period, apparently contributing to the differences. Ellsworth's predicted energy consumption was also significantly different from the actual energy consumption. A possible reason for Ellsworth's unexpected statistical results could be the effect of this base's numerous missile silos. Another possible reason is related to the energy projects performed at Ellsworth. The amount of money spent on these projects (DPRJ variable) near the end of the test period was nine times the amount spent during the control period. Although the DPRJ variable was statistically insignificant, it could have been a factor in Ellsworth's results.

Resolution of Hypothesis 1. The results show that MLR seems to be a good predictor of energy consumption. Two of the four control base energy consumptions were accurately predicted. The other two control base energy consumptions were not accurately predicted, but probably explanations were found as noted above. The mixed results on these two

control bases does not discredit the effectiveness of MLR, however, because of the support described in the background section of this study.

Hypothesis 2. The goal for the EMCS bases was to have a significance of less than 0.1 using a paired T-test, which would mean that the predicted energy value would be greater than the actual energy value. The EMCS bases of Lackland, McGuire, Scott, and Offutt had significantly less actual energy consumption than was predicted. The bases of Keesler, Charleston, McClellan, and the Air Force Academy, though, had no significant difference between actual energy consumption and predicted energy consumption. However, three of these bases did have predicted energy values slightly greater than their actual energy values. Instead of having significance levels of less than 0.1 (significant difference) their significance levels were between 0.30 and 0.47. The fourth base had predicted energy values slightly less than the actual energy values.

There are possible reasons why these four EMCS bases were not significant as determined from interviewing the supervisors and/or operators at these bases. Keesler had their EMCS installed in 1978, but it was considered operational for only the last 17 months of this study. The lack of any significant energy savings could possibly be due to the short operating period of the EMCS. At Charleston the supervisor had said they have had an operational EMCS for

nine years while the AFESC stated that it had only been operational for five years. There should be no significance then before EMCS and after EMCS since in actuality the EMCS was running during the whole period. McClellan's problem is that it is a major maintenance base where an enormous amount of energy is used in maintenance processing. Every year more and more of the total energy consumption is being identified as process energy. In order to clearly evaluate the facility energy consumption trends, the process energy should have been identified completely and consistently, since it is not evaluated under the same energy policies as facility energy. Further, McClellan's energy consumption has steadily gone up which is the opposite of all non-maintenance bases. The Air Force Academy did not use its EMCS for energy management until the last six months. Because of lack of operator knowledge and training, the system was used only for monitoring until the present supervisor arrived and programmed the EMCS for energy management.

Resolution of Hypothesis 2. The results show that EMCS can possibly save energy since four of the eight EMCS bases exhibited less energy actually consumed than was predicted by the statistical model. Although these results were statistically significant, they represented only approximately one percent energy savings. However, because of the factors mentioned above and the minute calculated savings, the regression and associated analysis could not conclusively prove that the EMCS's are saving energy for the Air Force.

Recommendations

Following are recommendations for further research in the attempt to prove or disprove EMCS energy saving capabilities:

1. Researchers should expand this effort by obtaining more complete data on base population, base square footage, dollar value of energy projects and any other pertinent data that could have an impact on energy consumption.

2. Researchers using the same data as in 1 above, should try other statistical models and variables to determine if better verification of energy savings can be obtained.

3. Researchers should begin metering facilities at a base where EMCS is not operating but will be installed approximately two years or more in the future. This could provide accurate comparisons of before and after EMCS operation.

4. Researchers should visit each of the EMCS bases to determine how well the EMCS's are operating, what they really do, and the condition of the HVAC systems that the EMCS's are controlling.

APPENDICES

APPENDIX A

DATA FILES FOR SAMPLE BASES

This appendix includes the data files for each of the twelve bases analyzed in this thesis. The first page depicts the format of the data files with definitions of the variables related to each column of data.

DATA FILE FORMAT

```
BA PD YM     AREA     POP    HD   CD    DPRJ      EPRJ      NRGY
-- - ---- -------- ----- ---- --- ------- --------- ------
123456789112345678921234567893123456789412345678951234567896
```

THE ABOVE STRING OF NUMBERS INDICATES THE COLUMN NUMBERS OF THE DATA ELEMENTS. THE VARIABLES ARE DEFINED AS FOLLOWS:

BA = BASE NUMBER, 1 THROUGH 12.

PD = PERIOD, CONTROL (0) OR TEST (1) PORTION OF THE ANALYSIS PERIOD.

YM = YEAR-MONTH OF DATA RECORD.

AREA = SQUARE FOOTAGE BUILDING AREA OF THE BASE.

POP = BASE POPULATION.

HD = HEATING DEGREE DAYS FOR THE MONTH.

CD = COOLING DEGREE DAYS FOR THE MONTH.

DPRJ = DOLLAR COST OF THE ENERGY PROJECTS.

EPRJ = ENERGY OF THE ENERGY PROJECTS IN MILLION BTU'S (MBTU) PER YEAR. THIS VARIABLE WAS NOT USED IN THE FINAL ANALYSIS.

NRGY = ENERGY CONSUMPTION FOR THE MONTH IN MILLION BTU'S (MBTU).

DATA FILE FOR KEESLER AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
01	0	7410	08465452	00000	0002	176	0000000	000000.00	220932
01	0	7411	8465452	0	179	47	0	0.00	226313
01	0	7412	8465452	0	344	9	0	0.00	214170
01	0	7501	8465452	15654	282	16	0	0.00	198572
01	0	7502	8465452	15654	165	48	0	0.00	200267
01	0	7503	8465452	15654	167	68	0	0.00	193224
01	0	7504	8465452	15654	55	112	0	0.00	190276
01	0	7505	8465452	15654	0	384	0	0.00	227005
01	0	7506	8465452	15654	0	493	0	0.00	245557
01	0	7507	8465452	15654	0	486	0	0.00	254214
01	0	7508	8465452	15654	0	484	0	0.00	261614
01	0	7509	8465452	15654	1	348	0	0.00	266776
01	0	7510	8545077	15654	7	189	0	0.00	204648
01	0	7511	8545077	15654	176	118	0	0.00	235829
01	0	7512	8545077	15654	324	23	0	0.00	225207
01	0	7601	8545077	14068	472	0	0	0.00	238000
01	0	7602	8545077	14068	191	17	0	0.00	198585
01	0	7603	8545077	14068	87	79	0	0.00	170011
01	0	7604	8545077	14068	16	176	0	0.00	171529
01	0	7605	8545077	14068	0	283	0	0.00	201372
01	0	7606	8545077	14068	0	489	0	0.00	224504
01	0	7607	8545077	14068	0	586	0	0.00	231066
01	0	7608	8545077	14068	0	532	20400	622.20	264547
01	0	7609	8545077	14068	0	378	20400	622.20	253916
01	0	7610	8570422	14068	134	57	20400	622.20	220657
01	0	7611	8570422	14068	419	0	115400	3700.20	233296
01	0	7612	8570422	14068	485	0	178400	6358.80	221209
01	0	7701	8570422	13502	685	0	178400	6358.80	247168
01	0	7702	8570422	13502	281	5	178400	6358.80	199172
01	0	7703	8570422	13502	96	101	178400	6358.80	169128
01	0	7704	8570422	13502	10	190	178400	6358.80	184018
01	0	7705	8570422	13502	0	418	178400	6358.80	204048
01	0	7706	8570422	13502	0	634	178400	6358.80	238436
01	0	7707	8570422	13502	0	665	178400	6358.80	248561
01	0	7708	8570422	13502	0	600	178400	6358.80	258483
01	0	7709	8570422	13502	0	540	178400	6358.80	244352
01	0	7710	8699776	13502	57	146	385376	6358.80	202178
01	0	7711	8699776	13502	112	46	385376	6358.80	209630
01	0	7712	8699776	13502	394	6	385376	6358.80	199423
01	0	7801	8699776	12853	646	0	385376	6358.80	248193
01	0	7802	8699776	12853	529	0	385376	6358.80	224727
01	0	7803	8699776	12853	231	10	385376	6358.80	191047
01	0	7804	8699776	12853	16	120	385376	6358.80	180023
01	0	7805	8699776	12853	0	323	385376	6358.80	204703
01	0	7806	8699776	12853	0	475	385376	6358.80	[illegible]
01	0	7807	8699776	12853	0	488	385376	6358.80	[illegible]
01	0	7808	8699776	12853	0	508	385376	6358.80	[illegible]
01	0	7809	8699776	12853	0	406	385376	[illegible]	[illegible]

AD-A134 384 ENERGY MANAGEMENT AND CONTROL SYSTEM VERIFICATION STUDY 2/2
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH
SCHOOL OF SYSTEMS AND LOGISTICS K E BOULWARE ET AL.
UNCLASSIFIED SEP 83 AFIT-LSSR-37-83 F/G 5/1 NL

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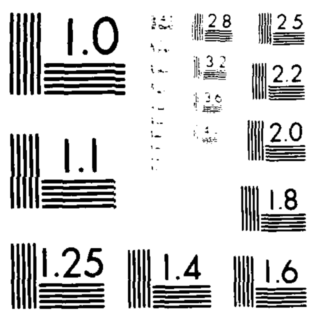

MICROCOPY RESOLUTION TEST CHART

DATA FILE FOR KEESLER AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
01	0	7810	8699776	12853	22	137	385376	6358.80	236115
01	0	7811	8699776	12853	66	61	385376	6358.80	187476
01	0	7812	8699776	12853	330	27	385376	6358.80	218696
01	0	7901	8699776	13566	589	0	385376	6358.80	245239
01	0	7902	8699776	13566	378	3	385376	6358.80	206101
01	0	7903	8699776	13566	138	28	385376	6358.80	159511
01	0	7904	8699776	13566	6	164	385376	6358.80	187011
01	0	7905	8699776	13566	1	288	385376	6358.80	193479
01	0	7906	8699776	13566	0	463	385376	6358.80	219949
01	0	7907	8699776	13566	0	545	385376	6358.80	257627
01	0	7908	8699776	13566	0	581	385376	6358.80	256679
01	0	7909	8699776	13566	0	424	385376	6358.80	245270
01	0	7910	8711043	13566	19	189	385376	6358.80	192037
01	0	7911	8711043	13566	213	18	385376	6358.80	197447
01	0	7912	8711043	13566	351	5	385376	6358.80	198799
01	0	8001	8711043	15443	251	0	385376	6358.80	190443
01	0	8002	8711043	15443	401	2	385376	6358.80	184406
01	0	8003	8711043	15443	165	39	385376	6358.80	156474
01	0	8004	8711043	15443	30	89	385376	6358.80	163027
01	0	8005	8711043	15443	0	333	385376	6358.80	181970
01	0	8006	8711043	15443	0	526	385376	6358.80	242905
01	0	8007	8711043	15443	0	608	385376	6358.80	261662
01	0	8008	8711043	15443	0	594	385376	6358.80	250189
01	0	8009	8711043	15443	0	517	385376	6358.80	272437
01	0	8010	9253923	15443	38	127	582926	6358.80	228172
01	0	8011	9253923	15443	190	36	582926	6358.80	203350
01	0	8012	9253923	15443	351	11	582926	6358.80	211772
01	0	8101	9253923	14313	541	0	582926	6358.80	215830
01	0	8102	9253923	14313	330	0	582926	6358.80	202336
01	0	8103	9253923	14313	217	13	582926	6358.80	187742
01	0	8104	9253923	14313	7	181	582926	6358.80	172519
01	1	8105	9253923	14313	0	243	582926	6358.80	210859
01	1	8106	9253923	14313	0	565	582926	6358.80	254218
01	1	8107	9253923	14313	0	677	582926	6358.80	262313
01	1	8108	9253923	14313	0	624	582926	6358.80	278661
01	1	8109	9253923	14313	1	415	582926	6358.80	236315
01	1	8110	8983167	14313	30	215	582926	6358.80	221738
01	1	8111	8983167	14313	81	81	582926	6358.80	172267
01	1	8112	8983167	14313	372	2	582926	6358.80	183364
01	1	8201	8983167	14370	414	3	636326	6358.80	192017
01	1	8202	8983167	14370	280	2	636326	6358.80	184866
01	1	8203	8983167	14370	151	93	636326	6358.80	166539
01	1	8204	8983167	14370	47	112	636326	6358.80	172071
01	1	8205	8983167	14370	0	334	820287	6358.80	172994
01	1	8206	8983167	14370	0	521	820287	6358.80	245133
01	1	8207	8983167	14370	0	533	820287	6358.80	242225
01	1	8208	8983167	14370	0	537	820287	6358.80	244055
01	1	8209	8983167	14370	0	372	820287	6358.80	240894

DATA FILE FOR LACKLAND AFB

BA	FD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
02	0	7410	09477539	00000	0010	172	0000000	000000.00	178885
02	0	7411	9477539	0	221	43	0	0.00	184418
02	0	7412	9477539	0	403	7	0	0.00	205304
02	0	7501	9477539	0	327	35	0	0.00	197545
02	0	7502	9477539	0	298	3	0	0.00	185186
02	0	7503	9477539	0	141	60	0	0.00	195859
02	0	7504	9477539	0	27	167	0	0.00	174458
02	0	7505	9477539	0	0	297	0	0.00	207974
02	0	7506	9477539	0	0	453	0	0.00	233164
02	0	7507	9477539	33851	0	536	0	0.00	244164
02	0	7508	9477539	33789	0	537	0	0.00	254556
02	0	7509	9477539	33450	1	340	0	0.00	214604
02	0	7510	9575542	33825	17	215	0	0.00	196943
02	0	7511	9575542	32751	200	82	0	0.00	194618
02	0	7512	9575542	33020	392	26	0	0.00	212446
02	0	7601	9575542	31699	466	1	0	0.00	214551
02	0	7602	9575542	32871	180	44	0	0.00	156452
02	0	7603	9575542	31808	148	106	0	0.00	162701
02	0	7604	9575542	30253	16	84	0	0.00	142178
02	0	7605	9575542	29941	17	142	0	0.00	165652
02	0	7606	9575542	31148	0	468	0	0.00	214037
02	0	7607	9575542	32897	0	486	0	0.00	225331
02	0	7608	9575542	33418	0	590	0	0.00	234948
02	0	7609	9575542	33172	0	440	0	0.00	215335
02	0	7610	9776974	32968	112	64	0	0.00	180768
02	0	7611	9776974	30623	325	4	0	0.00	196112
02	0	7612	9776974	29475	517	0	0	0.00	210067
02	0	7701	9776974	30330	653	0	0	0.00	234539
02	0	7702	9776974	31453	282	2	0	0.00	177609
02	0	7703	9776974	31052	136	47	0	0.00	173928
02	0	7704	9776974	30034	30	97	0	0.00	138294
02	0	7705	9776974	28771	0	307	0	0.00	197703
02	0	7706	9776974	30846	0	491	0	0.00	232722
02	0	7707	9776974	32065	0	619	0	0.00	242037
02	0	7708	9776974	30639	0	654	0	0.00	241895
02	0	7709	9776974	30228	0	555	0	0.00	229869
02	0	7710	9886561	29926	19	222	0	0.00	172017
02	0	7711	9886561	28299	125	39	0	0.00	159306
02	0	7712	9886561	28401	337	9	0	0.00	182557
02	0	7801	9886561	29009	604	4	0	0.00	221633
02	0	7802	9886561	29238	484	9	0	0.00	194399
02	0	7803	9886561	29239	167	42	0	0.00	173351
02	0	7804	9886561	29182	15	210	0	0.00	136356
02	0	7805	9886561	28442	0	472	0	0.00	215102
02	0	7806	9886561	30340	0	581	0	0.00	227181
02	0	7807	9886561	31628	0	715	0	0.00	251708
02	0	7808	9886561	31997	0	572	0	0.00	248342
02	0	7809	9886561	31422	0	420	0	0.00	333253

DATA FILE FOR LACKLAND AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
02	0	7810	9886561	30382	3	185	0	0.00	165596
02	0	7811	9886561	28517	124	93	0	0.00	165273
02	0	7812	9886561	28034	356	13	0	0.00	193888
02	0	7901	9886561	27475	626	1	0	0.00	233904
02	0	7902	9886561	27834	349	14	0	0.00	189686
02	0	7903	9886561	27363	104	53	0	0.00	175658
02	0	7904	9886561	26819	23	151	0	0.00	149617
02	1	7905	9886561	26232	1	302	0	0.00	172293
02	1	7906	9886561	28272	0	418	0	0.00	152624
02	1	7907	9886561	30114	0	541	0	0.00	177327
02	1	7908	9886561	30930	0	553	0	0.00	198545
02	1	7909	9886561	30865	0	370	0	0.00	217623
02	1	7910	10810053	30772	24	279	0	0.00	189746
02	1	7911	10810053	29405	259	37	0	0.00	179623
02	1	7912	10810053	28682	338	10	0	0.00	191576
02	1	8001	10810053	29075	359	11	0	0.00	196404
02	1	8002	10810053	29379	331	16	0	0.00	196036
02	1	8003	10810053	29479	138	83	0	0.00	173739
02	1	8004	10810053	28371	25	188	0	0.00	152745
02	1	8005	10810053	26724	0	353	0	0.00	198382
02	1	8006	10810053	29268	0	649	0	0.00	231330
02	1	8007	10810053	31208	0	730	0	0.00	249309
02	1	8008	10810053	32263	0	641	0	0.00	238823
02	1	8009	10810053	31589	0	553	0	0.00	229808
02	1	8010	10691644	30251	52	249	0	0.00	194639
02	1	8011	10691644	29558	227	33	0	0.00	191533
02	1	8012	10691644	29080	266	26	0	0.00	194627
02	1	8101	10691644	28796	334	3	0	0.00	201111
02	1	8102	10691644	30496	258	40	0	0.00	184553
02	1	8103	10691644	29804	102	56	0	0.00	178947
02	1	8104	10691644	28172	0	285	0	0.00	180432
02	1	8105	10691644	28417	0	396	0	0.00	213094
02	1	8106	10691644	29828	0	497	0	0.00	234973
02	1	8107	10691644	31239	0	593	0	0.00	249731
02	1	8108	10691644	32001	0	588	0	0.00	255164
02	1	8109	10691644	32768	4	400	0	0.00	231092
02	1	8110	10602260	32497	60	230	0	0.00	191987
02	1	8111	10602260	29496	133	32	0	0.00	177948
02	1	8112	10602260	29246	377	1	0	0.00	205043
02	1	8201	10602260	28827	394	32	0	0.00	211117
02	1	8202	10602260	30123	359	13	0	0.00	165712
02	1	8203	10602260	29430	114	169	0	0.00	189674
02	1	8204	10602260	27780	50	212	0	0.00	168401
02	1	8205	10602260	28010	0	324	0	0.00	192115
02	1	8206	10602260	29900	0	549	0	0.00	253119
02	1	8207	10602260	30242	0	665	0	0.00	253149
02	1	8208	10602260	30413	0	667	0	0.00	254763
02	1	8209	10602260	30322	0	470	0	0.00	219323

DATA FILE FOR CHARLESTON AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
03	0	7410	03733593	06110	0136	046	0000000	000000.00	081806
03	0	7411	3733593	6110	299	18	0	0.00	94248
03	0	7412	3733593	6110	432	3	96340	0.00	105033
03	0	7501	3733593	6164	350	8	96340	0.00	108565
03	0	7502	3733593	6164	294	13	96340	0.00	88736
03	0	7503	3733593	6164	273	26	96340	0.00	87458
03	0	7504	3733593	6164	152	74	96340	0.00	79235
03	0	7505	3733593	6164	0	318	96340	0.00	92124
03	0	7506	3733593	6164	0	414	96340	0.00	113175
03	0	7507	3733593	6164	0	449	96340	0.00	120933
03	0	7508	3733593	6164	0	516	96340	0.00	117456
03	0	7509	3733593	6164	0	361	141007	0.00	106909
03	0	7510	3739093	6164	40	171	141007	0.00	86132
03	0	7511	3739093	6164	221	58	141007	0.00	88652
03	0	7512	3739093	6164	466	0	244107	0.00	109416
03	0	7601	3739093	6114	624	2	244107	0.00	128357
03	0	7602	3739093	6114	265	9	244107	0.00	102485
03	0	7603	3739093	6114	146	73	244107	0.00	90786
03	0	7604	3739093	6114	94	70	244107	0.00	78637
03	0	7605	3739093	6114	15	187	244107	0.00	95137
03	0	7606	3739093	6114	3	329	244107	0.00	98548
03	0	7607	3739093	6114	0	502	244107	0.00	114836
03	0	7608	3739093	6114	0	384	244107	0.00	104320
03	0	7609	3739093	6114	0	274	244107	0.00	101087
03	0	7610	3744752	6114	159	52	244107	0.00	88478
03	0	7611	3744752	6114	418	2	244107	0.00	107061
03	0	7612	3744752	6114	501	1	244107	0.00	118411
03	0	7701	3744752	6114	804	0	244107	0.00	139233
03	0	7702	3744752	6114	516	1	442507	17994.88	108577
03	0	7703	3744752	5649	186	54	442507	17994.88	91645
03	0	7704	3744752	5649	58	107	442507	17994.88	67781
03	0	7705	3744752	5649	17	263	442507	17994.88	71579
03	0	7706	3744752	5649	0	493	442507	17994.88	95335
03	0	7707	3744752	5649	0	588	442507	17994.88	100371
03	0	7708	3744752	5649	0	518	442507	17994.88	92386
03	0	7709	3744752	5649	0	417	442507	17994.88	89192
03	0	7710	3733262	5649	112	71	442507	17994.88	75374
03	0	7711	3733262	5649	175	71	1765607	185102.41	83835
03	0	7712	3733262	5649	459	1	1765607	185102.41	108260
03	1	7801	3733262	5649	663	0	1765607	185102.41	133799
03	1	7802	3733262	5649	616	0	1765607	185102.41	126175
03	1	7803	3733262	5649	309	13	2601907	185102.41	103426
03	1	7804	3733262	5993	52	106	2601907	185102.41	56854
03	1	7805	3733262	5993	18	242	2601907	185102.41	64527
03	1	7806	3733262	5993	0	414	2601907	185102.41	75164
03	1	7807	3733262	5993	0	505	2601907	185102.41	85959
03	1	7808	3733262	5993	0	514	2601907	185102.41	90911
03	1	7809	3733262	5993	0	378	2601907	185102.41	78141

DATA FILE FOR CHARLESTON AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
03	1	7810	3924473	5993	57	86	2601907	185102.41	67747
03	1	7811	3924473	5993	83	40	2601907	185102.41	58724
03	1	7812	3924473	5993	399	21	2601907	185102.41	101947
03	1	7901	3924473	5993	602	0	2601907	185102.41	129820
03	1	7902	3924473	5993	505	2	2601907	185102.41	116083
03	1	7903	3924473	5993	241	9	2601907	185102.41	95720
03	1	7904	3924473	5587	70	71	2601907	185102.41	57185
03	1	7905	3924473	5587	2	241	2601907	185102.41	61925
03	1	7906	3924473	5587	0	335	2601907	185102.41	70019
03	1	7907	3924473	5587	0	533	2601907	185102.41	85055
03	1	7908	3924473	5587	0	514	2601907	185102.41	86118
03	1	7909	3924473	5587	0	354	2601907	185102.41	75925
03	1	7910	3983100	5587	68	105	2601907	185102.41	63234
03	1	7911	3983100	5587	203	40	2601907	185102.41	87300
03	1	7912	3983100	5587	500	0	2601907	185102.41	114670
03	1	8001	3983100	5587	495	0	2601907	185102.41	119531
03	1	8002	3983100	5587	555	9	2601907	185102.41	121580
03	1	8003	3983100	5587	321	7	2601907	185102.41	98748
03	1	8004	3983100	5445	82	69	2601907	185102.41	53985
03	1	8005	3983100	5445	17	221	2601907	185102.41	61875
03	1	8006	3983100	5445	0	407	2601907	185102.41	74013
03	1	8007	3983100	5445	0	549	2601907	185102.41	91509
03	1	8008	3983100	5445	0	539	2601907	185102.41	85498
03	1	8009	3983100	5445	0	451	2601907	185102.41	83151
03	1	8010	4011184	5445	80	87	2601907	185102.41	62857
03	1	8011	4011184	5445	287	5	2601907	185102.41	87760
03	1	8012	4011184	5445	537	1	2960392	185102.41	105851
03	1	8101	4011184	5445	719	0	2960392	185102.41	130779
03	1	8102	4011184	5445	393	0	2960392	185102.41	105510
03	1	8103	4011184	5445	333	9	2960392	185102.41	93815
03	1	8104	4011184	5483	55	138	2960392	185102.41	55884
03	1	8105	4011184	5483	16	199	2960392	185102.41	57376
03	1	8106	4011184	5483	0	539	2960392	185102.41	95991
03	1	8107	4011184	5483	0	582	2960392	185102.41	88388
03	1	8108	4011184	5483	0	481	2960392	185102.41	79990
03	1	8109	4011184	5483	3	307	2960392	185102.41	73406
03	1	8110	4011184	5483	88	66	2960392	185102.41	73981
03	1	8111	4011184	5483	291	9	2960392	185102.41	91165
03	1	8112	4011184	5483	577	0	2960392	185102.41	120602
03	1	8201	4011184	5483	611	0	2960392	185102.41	134582
03	1	8202	4011184	5483	372	2	2960392	185102.41	119145
03	1	8203	4011184	5483	214	42	2960392	185102.41	88330
03	1	8204	4011184	5403	132	42	3247392	185102.41	55464
03	1	8205	4011184	5403	3	232	3247392	185102.41	62324
03	1	8206	4011184	5403	0	420	3247392	185102.41	86884
03	1	8207	4011184	5403	0	510	3247392	185102.41	89962
03	1	8208	4011184	5403	0	475	3247392	185102.41	94464
03	1	8209	4011184	5403	0	293	3247392	185102.41	71879

DATA FILE FOR MCCLELLAN AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
04	0	7410	10480848	00000	0047	088	0000000	000000.00	159462
04	0	7411	10480848	0	354	0	0	0.00	216086
04	0	7412	10480848	0	576	0	0	0.00	254629
04	0	7501	10480848	0	641	0	0	0.00	261650
04	0	7502	10480848	0	397	0	0	0.00	253456
04	0	7503	10480848	0	353	0	0	0.00	227863
04	0	7504	10480848	0	294	1	0	0.00	214108
04	0	7505	10480848	0	45	172	0	0.00	174056
04	0	7506	10480848	0	3	250	0	0.00	169246
04	0	7507	10480848	0	0	365	0	0.00	156586
04	0	7508	10480848	0	0	336	0	0.00	158511
04	0	7509	10480848	0	0	336	0	0.00	162914
04	0	7510	10743275	0	131	53	0	0.00	167682
04	0	7511	10743275	0	391	0	0	0.00	235973
04	0	7512	10743275	0	557	0	0	0.00	271949
04	0	7601	10743275	0	564	0	0	0.00	262907
04	0	7602	10743275	0	391	0	0	0.00	231889
04	0	7603	10743275	0	365	1	0	0.00	208931
04	0	7604	10743275	0	219	11	0	0.00	192930
04	0	7605	10743275	0	0	159	0	0.00	158884
04	0	7606	10743275	0	3	257	0	0.00	147113
04	0	7607	10743275	0	0	419	0	0.00	160286
04	0	7608	10743275	16829	2	266	0	0.00	160581
04	0	7609	10743275	17039	0	243	0	0.00	159708
04	0	7610	10763080	17009	45	74	0	0.00	159943
04	0	7611	10763080	16635	285	0	0	0.00	213399
04	0	7612	10763080	16728	577	0	0	0.00	246780
04	0	7701	10763080	16697	670	0	0	0.00	273332
04	0	7702	10763080	16689	339	0	0	0.00	211051
04	0	7703	10763080	16682	395	0	0	0.00	263877
04	0	7704	10763080	16351	67	21	0	0.00	175093
04	0	7705	10763080	16326	148	36	0	0.00	171920
04	0	7706	10763080	16344	3	321	0	0.00	150835
04	0	7707	10763080	16169	0	380	0	0.00	160612
04	0	7708	10763080	16126	0	369	0	0.00	150987
04	0	7709	10763080	16173	7	196	0	0.00	144615
04	0	7710	11363846	16333	60	60	0	0.00	146432
04	0	7711	11363846	16348	272	0	0	0.00	205260
04	0	7712	11363846	16311	437	0	0	0.00	229281
04	0	7801	11363846	16281	484	0	0	0.00	237373
04	0	7802	11363846	16242	400	0	0	0.00	215419
04	0	7803	11363846	16369	196	0	0	0.00	200701
04	0	7804	11363846	16381	257	0	0	0.00	181023
04	0	7805	11363846	16451	56	88	0	0.00	166201
04	0	7806	11363846	16520	0	198	0	0.00	163765
04	0	7807	11363846	16599	0	379	0	0.00	163945
04	0	7808	11363846	16645	0	387	0	0.00	158574
04	0	7809	11363846	16529	30	133	0	0.00	157155

DATA FILE FOR MCCLELLAN AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
04	0	7810	11356915	16695	54	84	0	0.00	160854
04	0	7811	11356915	16700	449	0	0	0.00	216469
04	0	7812	11356915	16589	708	0	0	0.00	273267
04	1	7901	11356915	16460	601	0	0	0.00	245529
04	1	7902	11356915	16421	428	0	0	0.00	245289
04	1	7903	11356915	16382	327	0	0	0.00	193507
04	1	7904	11356915	16338	215	0	0	0.00	158403
04	1	7905	11356915	16338	82	85	0	0.00	144147
04	1	7906	11356915	16123	6	199	0	0.00	158113
04	1	7907	11356915	16076	2	379	0	0.00	256357
04	1	7908	11356915	15973	0	340	0	0.00	153980
04	1	7909	11356915	15906	0	345	0	0.00	167052
04	1	7910	11289868	15882	93	80	0	0.00	146525
04	1	7911	11289868	15880	385	0	0	0.00	206399
04	1	7912	11289868	15848	600	0	0	0.00	221795
04	1	8001	11289868	15779	545	0	0	0.00	213986
04	1	8002	11289868	15806	335	0	0	0.00	218460
04	1	8003	11289868	15736	354	0	0	0.00	188744
04	1	8004	11289868	15816	157	15	0	0.00	160037
04	1	8005	11289868	15744	59	74	0	0.00	148364
04	1	8006	11289868	15731	8	166	0	0.00	156541
04	1	8007	11289868	15714	0	410	0	0.00	157391
04	1	8008	11289868	15101	0	227	0	0.00	160910
04	1	8009	11289868	15107	4	158	0	0.00	160188
04	1	8010	11305446	15149	135	109	0	0.00	161429
04	1	8011	11305446	15149	308	0	0	0.00	204506
04	1	8012	11305446	15190	537	0	0	0.00	212669
04	1	8101	11305446	15200	493	0	0	0.00	224620
04	1	8102	11305446	15582	353	0	0	0.00	215672
04	1	8103	11305446	15601	318	0	0	0.00	196146
04	1	8104	11305446	15642	146	45	0	0.00	163511
04	1	8105	11305446	15658	12	176	0	0.00	162665
04	1	8106	11305446	15820	0	462	0	0.00	157965
04	1	8107	11305446	15982	0	467	0	0.00	164909
04	1	8108	11305446	16238	0	334	0	0.00	171162
04	1	8109	11305446	16305	1	276	0	0.00	161378
04	1	8110	11305446	16542	83	37	0	0.00	173622
04	1	8111	11305446	16671	240	0	0	0.00	210061
04	1	8112	11305446	16712	415	0	0	0.00	236742
04	1	8201	11305446	16948	650	0	0	0.00	256496
04	1	8202	11305446	16948	364	0	0	0.00	220338
04	1	8203	11305446	17183	361	0	0	0.00	209907
04	1	8204	11305446	17271	212	4	0	0.00	199147
04	1	8205	11305446	17225	23	115	0	0.00	156148
04	1	8206	11305446	17179	10	145	0	0.00	158425
04	1	8207	11305446	17165	0	389	0	0.00	172631
04	1	8208	11305446	17031	0	331	0	0.00	167763
04	1	8209	11305446	16896	18	170	0	0.00	168508

DATA FILE FOR MCGUIRE AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
05	0	7410	05810423	07344	0371	001	0000000	000000.00	129406
05	0	7411	5810423	7344	550	7	0	0.00	161338
05	0	7412	5810423	7344	827	0	0	0.00	196165
05	0	7501	5810423	7320	871	0	0	0.00	191656
05	0	7502	5810423	7320	820	0	0	0.00	210196
05	0	7503	5810423	7320	764	0	0	0.00	193668
05	0	7504	5810423	7320	517	2	0	0.00	162889
05	0	7505	5810423	7320	94	88	0	0.00	109145
05	0	7506	5810423	7320	14	180	0	0.00	95612
05	0	7507	5810423	7320	0	336	0	0.00	101239
05	0	7508	5810423	7320	2	293	0	0.00	110962
05	0	7509	5810423	7320	73	50	0	0.00	99187
05	0	7510	5806078	7320	216	18	0	0.00	94496
05	0	7511	5806078	7320	399	10	0	0.00	147857
05	0	7512	5806078	7320	828	0	0	0.00	191125
05	0	7601	5806078	7173	1130	0	0	0.00	254278
05	0	7602	5806078	7173	697	0	0	0.00	214035
05	0	7603	5806078	7173	623	0	0	0.00	179454
05	0	7604	5806078	7173	377	40	0	0.00	137429
05	0	7605	5806078	7173	199	25	0	0.00	105121
05	0	7606	5806078	7173	34	251	0	0.00	105315
05	0	7607	5806078	7173	0	220	0	0.00	115720
05	0	7608	5806078	7173	14	252	0	0.00	108732
05	0	7609	5806078	7173	97	60	0	0.00	98715
05	0	7610	5820183	7173	392	3	0	0.00	118006
05	0	7611	5820183	7173	687	0	0	0.00	186773
05	0	7612	5820183	7173	1113	0	0	0.00	201749
05	0	7701	5820183	7173	1385	0	0	0.00	249517
05	0	7702	5820183	7173	895	0	0	0.00	215010
05	0	7703	5820183	6678	594	9	0	0.00	148265
05	0	7704	5820183	6678	376	17	0	0.00	117158
05	0	7705	5820183	6678	112	73	0	0.00	89423
05	0	7706	5820183	6678	33	148	0	0.00	89524
05	0	7707	5820183	6678	1	334	0	0.00	101190
05	0	7708	5820183	6678	2	289	203000	4100.60	98416
05	0	7709	5820183	6678	33	154	203000	4100.60	94533
05	0	7710	5855630	6678	338	1	203000	4100.60	103698
05	0	7711	5855630	6678	534	2	203000	4100.60	144413
05	0	7712	5855630	6678	960	0	203000	4100.60	192220
05	1	7801	5855630	6678	1094	0	203000	4100.60	229033
05	1	7802	5855630	6678	1124	0	203000	4100.60	221997
05	1	7803	5855630	6678	828	0	203000	4100.60	191570
05	1	7804	5855630	7245	403	0	203000	4100.60	139355
05	1	7805	5855630	7245	161	48	203000	4100.60	103611
05	1	7806	5855630	7245	13	175	203000	4100.60	90452
05	1	7807	5855630	7245	4	211	203000	4100.60	103541
05	1	7808	5855630	7245	0	346	203000	4100.60	99544
05	1	7809	5855630	7245	93	85	203000	4100.60	96565

DATA FILE FOR MCGUIRE AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
05	1	7810	5856434	7245	311	5	203000	4100.60	113415
05	1	7811	5856434	7245	504	0	203000	4100.60	142671
05	1	7812	5856434	7245	856	0	203000	4100.60	175599
05	1	7901	5856434	7245	981	0	203000	4100.60	220491
05	1	7902	5856434	7245	1150	0	203000	4100.60	224981
05	1	7903	5856434	7245	592	0	203000	4100.60	181892
05	1	7904	5856434	6397	441	0	203000	4100.60	145866
05	1	7905	5856434	6397	116	35	203000	4100.60	95097
05	1	7906	5856434	6397	32	100	203000	4100.60	88615
05	1	7907	5856434	6397	6	273	203000	4100.60	99168
05	1	7908	5856434	6397	13	297	203000	4100.60	99392
05	1	7909	5856434	6397	30	121	203000	4100.60	100756
05	1	7910	5944359	6397	303	31	203000	4100.60	108163
05	1	7911	5944359	6397	451	1	203000	4100.60	157411
05	1	7912	5944359	6397	783	0	203000	4100.60	167152
05	1	8001	5944359	6397	1024	0	203000	4100.60	209502
05	1	8002	5944359	6397	1023	0	420400	11426.98	224946
05	1	8003	5944359	6397	750	0	420400	11426.98	188686
05	1	8004	5944359	6306	312	4	420400	11426.98	131318
05	1	8005	5944359	6306	70	90	420400	11426.98	93180
05	1	8006	5944359	6306	16	195	420400	11426.98	91264
05	1	8007	5944359	6306	0	442	420400	11426.98	110857
05	1	8008	5944359	6306	0	422	420400	11426.98	105466
05	1	8009	5944359	6306	40	204	420400	11426.98	100203
05	1	8010	6191176	6306	336	3	420400	11426.98	102806
05	1	8011	6191176	6306	662	0	420400	11426.98	159985
05	1	8012	6191176	6306	1016	0	420400	11426.98	174468
05	1	8101	6191176	6306	1237	0	420400	11426.98	225446
05	1	8102	6191176	6306	771	0	420400	11426.98	192881
05	1	8103	6191176	6306	751	0	420400	11426.98	176724
05	1	8104	6191176	6274	312	9	420400	11426.98	125835
05	1	8105	6191176	6274	151	52	420400	11426.98	91418
05	1	8106	6191176	6274	9	187	420400	11426.98	93093
05	1	8107	6191176	6274	0	320	420400	11426.98	111200
05	1	8108	6191176	6274	0	221	420400	11426.98	97884
05	1	8109	6191176	6274	44	108	420400	11426.98	93771
05	1	8110	6191176	6274	323	3	420400	11426.98	113866
05	1	8111	6191176	6274	527	0	420400	11426.98	146532
05	1	8112	6191176	6274	888	0	420400	11426.98	176408
05	1	8201	6191176	6274	1244	0	420400	11426.98	216850
05	1	8202	6191176	6274	821	0	420400	11426.98	215545
05	1	8203	6191176	6274	738	0	420400	11426.98	167031
05	1	8204	6191176	6276	469	2	420400	11426.98	144096
05	1	8205	6191176	6276	82	54	420400	11426.98	83935
05	1	8206	6191176	6276	25	145	420400	11426.98	92432
05	1	8207	6191176	6276	0	354	420400	11426.98	106356
05	1	8208	6191176	6276	13	218	420400	11426.98	100181
05	1	8209	6191176	6276	50	71	420400	11426.98	99449

DATA FILE FOR SCOTT AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
06	0	7410	05188320	07387	0225	030	0000000	000000.00	115324
06	0	7411	5188320	7387	579	1	0	0.00	125586
06	0	7412	5188320	7387	893	0	0	0.00	152205
06	0	7501	5188320	7363	929	0	0	0.00	174246
06	0	7502	5188320	7363	861	0	0	0.00	168627
06	0	7503	5188320	7363	726	0	0	0.00	147530
06	0	7504	5188320	7363	301	28	0	0.00	131815
06	0	7505	5188320	7363	24	173	0	0.00	113369
06	0	7506	5188320	7363	0	349	0	0.00	126555
06	0	7507	5188320	7363	1	404	0	0.00	136290
06	0	7508	5188320	7363	0	437	0	0.00	147142
06	0	7509	5188320	7363	83	143	0	0.00	125653
06	0	7510	5420424	7363	203	40	0	0.00	93945
06	0	7511	5420424	7363	489	5	0	0.00	128738
06	0	7512	5420424	7363	888	0	0	0.00	158471
06	0	7601	5420424	7566	1067	0	0	0.00	173399
06	0	7602	5420424	7566	633	0	0	0.00	145029
06	0	7603	5420424	7566	484	7	0	0.00	130584
06	0	7604	5420424	7566	308	33	0	0.00	109931
06	0	7605	5420424	7566	168	29	0	0.00	92533
06	0	7606	5420424	7566	0	216	0	0.00	122177
06	0	7607	5420424	7566	0	447	0	0.00	136310
06	0	7608	5420424	7566	0	279	0	0.00	136572
06	0	7609	5420424	7566	37	82	0	0.00	119695
06	0	7610	5263365	7566	450	13	0	0.00	125522
06	0	7611	5263365	7566	830	0	0	0.00	156921
06	0	7612	5263365	7566	1098	0	0	0.00	192289
06	0	7701	5263365	7566	1500	0	0	0.00	190384
06	0	7702	5263365	7566	827	0	0	0.00	173541
06	0	7703	5263365	8165	471	2	0	0.00	134327
06	0	7704	5263365	8165	178	40	0	0.00	110688
06	0	7705	5263365	8165	36	224	0	0.00	108760
06	0	7706	5263365	8165	2	302	0	0.00	129505
06	0	7707	5263365	8165	0	473	0	0.00	142395
06	0	7708	5263365	8165	0	358	0	0.00	123507
06	0	7709	5263365	8165	7	214	79000	6083.00	124929
06	0	7710	5534269	8165	291	2	79000	6083.00	104939
06	0	7711	5534269	8165	537	1	79000	6083.00	138415
06	0	7712	5534269	8165	1012	0	79000	6083.00	171567
06	0	7801	5534269	8165	1338	0	79000	6083.00	208982
06	0	7802	5534269	8165	1179	0	79000	6083.00	184016
06	0	7803	5534269	8165	830	1	79000	6083.00	168449
06	0	7804	5534269	9817	281	10	79000	6083.00	116571
06	0	7805	5534269	9817	169	110	79000	6083.00	100550
06	0	7806	5534269	9817	8	257	79000	6083.00	136346
06	0	7807	5534269	9817	0	398	79000	6083.00	143407
06	0	7808	5534269	9817	0	316	79000	6083.00	140126
06	0	7809	5534269	9817	38	205	79000	6083.00	129524

DATA FILE FOR SCOTT AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
06	0	7810	5571617	9817	332	2	79000	6083.00	114593
06	0	7811	5571617	9817	519	2	79000	6083.00	140369
06	0	7812	5571617	9817	926	0	79000	6083.00	172624
06	0	7901	5571617	9817	1469	0	180200	12347.28	204175
06	0	7902	5571617	9817	1181	0	180200	12347.28	188718
06	0	7903	5571617	9817	649	0	180200	12347.28	161861
06	0	7904	5571617	9482	363	6	180200	12347.28	142862
06	0	7905	5571617	9482	113	71	180200	12347.28	111697
06	0	7906	5571617	9482	0	279	180200	12347.28	122804
06	0	7907	5571617	9482	0	340	180200	12347.28	152528
06	0	7908	5571617	9482	4	304	180200	12347.28	125883
06	0	7909	5571617	9482	46	110	180200	12347.28	121432
06	0	7910	5573514	9482	274	42	180200	12347.28	109679
06	0	7911	5573514	9482	681	0	180200	12347.28	152368
06	0	7912	5573514	9482	848	0	180200	12347.28	16078[illegible]
06	0	8001	5573514	9482	1027	0	180200	12347.28	17689
06	0	8002	5573514	9482	1102	0	180200	12347.28	179670
06	1	8003	5573514	9482	744	0	180200	12347.28	162929
06	1	8004	5573514	9482	352	10	180200	12347.28	11922[illegible]
06	1	8005	5573514	9482	87	79	1453200	12347.28	9837[illegible]
06	1	8006	5573514	9482	11	257	2326200	32077.08	117204
06	1	8007	5573514	9482	0	565	2326200	32077.08	157465
06	1	8008	5573514	9482	0	541	2326200	32077.08	145932
06	1	8009	5573514	9482	38	203	2326200	32077.08	127368
06	1	8010	5575411	9482	318	31	2326200	32077.08	103253
06	1	8011	5575411	9482	614	1	2326200	32077.08	132876
06	1	8012	5575411	9482	908	0	2326200	32077.08	170870
06	1	8101	5575411	9482	1058	0	2326200	32077.08	173183
06	1	8102	5575411	9482	777	0	2326200	32077.08	159123
06	1	8103	5575411	9482	624	3	2326200	32077.08	151618
06	1	8104	5575411	9567	153	61	2373800	32077.08	115757
06	1	8105	5575411	9567	178	24	2373800	32077.08	99106
06	1	8106	5575411	9567	0	335	2373800	32077.08	133421
06	1	8107	5575411	9567	0	431	2373800	32077.08	148199
06	1	8108	5575411	9567	0	268	2373800	32077.08	130396
06	1	8109	5575411	9567	46	127	5814800	32077.08	116724
06	1	8110	5588604	9567	311	9	5814800	32077.08	108341
06	1	8111	5588604	9567	489	1	5814800	32077.08	122843
06	1	8112	5588604	9567	1004	0	5814800	32077.08	178364
06	1	8201	5588604	9567	1255	0	5814800	32077.08	187735
06	1	8202	5588604	9567	1034	0	5814800	32077.08	168515
06	1	8203	5588604	9567	581	0	5814800	32077.08	157901
06	1	8204	5588604	9738	417	2	5814800	32077.08	125770
06	1	8205	5588604	9738	9	183	5814800	32077.08	115817
06	1	8206	5588604	9738	7	181	5814800	32077.08	120155
06	1	8207	5588604	9738	0	445	5814800	32077.08	140287
06	1	8208	5588604	9738	0	309	5814800	32077.08	126631
06	1	8209	5588604	9738	46	141	5814800	32077.08	123044

DATA FILE FOR AIR FORCE ACADEMY

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
07	0	7410	07300528	00000	0498	000	0000000	000000.00	191173
07	0	7411	7300528	0	896	0	0	0.00	201337
07	0	7412	7300528	0	1165	0	0	0.00	236145
07	0	7501	7300528	8796	1110	0	0	0.00	236283
07	0	7502	7300528	8796	1028	0	0	0.00	208742
07	0	7503	7300528	8796	877	0	0	0.00	218488
07	0	7504	7300528	8796	700	0	0	0.00	195931
07	0	7505	7300528	8796	461	0	0	0.00	184705
07	0	7506	7300528	8796	49	0	0	0.00	94643
07	0	7507	7300528	8796	21	174	0	0.00	131282
07	0	7508	7300528	8796	30	160	0	0.00	144001
07	0	7509	7300528	8796	286	0	0	0.00	170170
07	0	7510	7358856	8796	526	0	0	0.00	183435
07	0	7511	7358856	8796	943	0	0	0.00	215202
07	0	7512	7358856	8796	942	0	0	0.00	206774
07	0	7601	7358856	8755	1044	0	0	0.00	223020
07	0	7602	7358856	8755	825	0	0	0.00	198228
07	0	7603	7358856	8755	989	0	0	0.00	220113
07	0	7604	7358856	8755	629	0	45000	0.00	184125
07	0	7605	7358856	8755	443	0	45000	0.00	158480
07	0	7606	7358856	8755	64	0	45000	0.00	109522
07	0	7607	7358856	8755	23	204	45000	0.00	137766
07	0	7608	7358856	8755	55	70	45000	0.00	147521
07	0	7609	7358856	8755	143	0	115000	51002.00	154390
07	0	7610	7360952	8755	699	0	115000	51002.00	204875
07	0	7611	7360952	8755	906	0	163000	59003.60	221346
07	0	7612	7360952	8755	1054	0	163000	59003.60	214686
07	0	7701	7360952	8654	1121	0	201000	68453.00	237471
07	0	7702	7360952	8654	921	0	835000	109668.00	162550
07	0	7703	7360952	8654	966	0	835000	109668.00	159983
07	0	7704	7360952	8654	603	0	945000	109668.00	148051
07	0	7705	7360952	8654	297	0	945000	109668.00	143070
07	0	7706	7360952	8654	20	0	1098000	117914.70	175058
07	0	7707	7360952	8654	16	190	1098000	117914.70	117830
07	0	7708	7360952	8654	56	108	1098000	117914.70	133711
07	0	7709	7360952	8654	173	0	1098000	117914.70	167041
07	0	7710	7361763	8654	546	0	1098000	117914.70	168771
07	0	7711	7361763	8654	846	0	1098000	117914.70	194136
07	0	7712	7361763	8654	950	0	1098000	117914.70	208777
07	0	7801	7361763	8942	1191	0	1098000	117914.70	233709
07	0	7802	7361763	8942	1002	0	1098000	117914.70	201114
07	0	7803	7361763	8942	801	0	1098000	117914.70	193506
07	0	7804	7361763	8942	582	0	1588000	117914.70	167106
07	0	7805	7361763	8942	435	0	1588000	117914.70	183233
07	0	7806	7361763	8942	108	30	1669000	125115.60	109399
07	0	7807	7361763	8942	15	200	1669000	125115.60	134978
07	0	7808	7361763	8942	79	88	1669000	125115.60	139491
07	0	7809	7361763	8942	201	2	1669000	125115.60	141636

DATA FILE FOR AIR FORCE ACADEMY CONTINUED

BA	FD	YM	AREA	POP	HD	CD	DFRJ	EFRJ	NRGY
07	0	7810	7362580	8942	528	0	1669000	125115.60	181544
07	0	7811	7362580	8942	869	0	1669000	125115.60	205235
07	0	7812	7362580	8942	1266	0	1669000	125115.60	215755
07	0	7901	7362580	8751	1404	0	1669000	125115.60	279569
07	0	7902	7362580	8751	943	0	1669000	125115.60	199028
07	0	7903	7362580	8751	911	0	1669000	125115.60	203493
07	0	7904	7362580	8751	640	0	2449000	125115.60	168998
07	0	7905	7362580	8751	492	0	2449000	125115.60	149424
07	0	7906	7362580	8751	79	24	2449000	125115.60	98091
07	0	7907	7362580	8751	31	56	2449000	125115.60	120737
07	0	7908	7362580	8751	107	40	2449000	125115.60	126694
07	0	7909	7362580	8751	203	11	2449000	125115.60	113337
07	0	7910	7371381	8751	544	0	2449000	125115.60	173088
07	0	7911	7371381	8751	1065	0	2449000	125115.60	212575
07	1	7912	7371381	8751	1005	0	2449000	125115.60	196019
07	1	8001	7371381	8719	1183	0	2449000	125115.60	223819
07	1	8002	7371381	8719	932	0	2449000	125115.60	202954
07	1	8003	7371381	8719	953	0	2449000	125115.60	201342
07	1	8004	7371381	8719	730	0	3194800	152104.26	170887
07	1	8005	7371381	8719	442	0	3194800	152104.26	151053
07	1	8006	7371381	8719	32	44	3194800	152104.26	91029
07	1	8007	7371381	8719	5	141	3194800	152104.26	109105
07	1	8008	7371381	8719	71	50	3194800	152104.26	117043
07	1	8009	7371381	8719	230	6	3194800	152104.26	129520
07	1	8010	7374448	8719	623	0	3194800	152104.26	165718
07	1	8011	7374448	8719	832	0	3194800	152104.26	177230
07	1	8012	7374448	8719	791	0	3194800	152104.26	182135
07	1	8101	7374448	0	999	0	3194800	152104.26	176927
07	1	8102	7374448	0	893	0	3194800	152104.26	187586
07	1	8103	7374448	0	920	0	3194800	152104.26	188503
07	1	8104	7374448	0	424	0	3194800	152104.26	149713
07	1	8105	7374448	0	436	0	3194800	152104.26	145312
07	1	8106	7374448	0	30	24	3194800	152104.26	100575
07	1	8107	7374448	0	29	70	3194800	152104.26	116502
07	1	8108	7374448	0	95	30	3194800	152104.26	126529
07	1	8109	7374448	0	208	1	3194800	152104.26	131929
07	1	8110	7371777	0	525	0	3194800	152104.26	159063
07	1	8111	7371777	0	644	0	3194800	152104.26	177614
07	1	8112	7371777	0	908	0	3194800	152104.26	196147
07	1	8201	7371777	0	981	0	3194800	152104.26	210475
07	1	8202	7371777	0	966	0	3194800	152104.26	179643
07	1	8203	7371777	0	850	0	3194800	152104.26	197091
07	1	8204	7371777	0	643	0	3294800	152104.26	167766
07	1	8205	7371777	0	439	0	3294800	152104.26	133978
07	1	8206	7371777	0	252	6	3294800	152104.26	112316
07	1	8207	7371777	0	22	98	3294800	152104.26	110613
07	1	8208	7371777	0	18	73	3294800	152104.26	126320
07	1	8209	7371777	0	246	12	3294800	152104.26	146691

DATA FILE FOR OFFUTT AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
08	0	7410	09121313	00000	0235	009	0000000	000000.00	182953
08	0	7411	9121313	0	726	0	0	0.00	210175
08	0	7412	9121313	0	1112	0	0	0.00	262547
08	0	7501	9121313	0	1310	0	0	0.00	272777
08	0	7502	9121313	0	1195	0	0	0.00	282710
08	0	7503	9121313	0	1040	0	0	0.00	256927
08	0	7504	9121313	0	493	4	0	0.00	214225
08	0	7505	9121313	0	79	94	0	0.00	174468
08	0	7506	9121313	0	17	186	0	0.00	203862
08	0	7507	9121313	0	2	369	0	0.00	248963
08	0	7508	9121313	0	0	370	0	0.00	250904
08	0	7509	9121313	0	183	54	0	0.00	190149
08	0	7510	9664576	0	284	30	0	0.00	197757
08	0	7511	9664576	0	741	0	0	0.00	209937
08	0	7512	9664576	0	1110	0	0	0.00	274618
08	0	7601	9664576	0	1269	0	0	0.00	292337
08	0	7602	9664576	0	846	0	0	0.00	251827
08	0	7603	9664576	0	798	0	0	0.00	242236
08	0	7604	9664576	0	303	17	0	0.00	179641
08	0	7605	9664576	35043	201	18	0	0.00	173261
08	0	7606	9664576	35043	12	191	0	0.00	216601
08	0	7607	9664576	35043	0	366	0	0.00	215410
08	0	7608	9664576	35903	0	339	0	0.00	235012
08	0	7609	9664576	35903	62	140	0	0.00	192191
08	0	7610	9659339	35903	488	24	191500	17994.24	199446
08	0	7611	9659339	33933	910	0	191500	17994.24	269823
08	0	7612	9659339	33933	1219	0	191500	17994.24	293114
08	0	7701	9659339	33933	1565	0	191500	17994.24	345942
08	0	7702	9659339	35235	884	0	191500	17994.24	271794
08	0	7703	9659339	35235	605	0	191500	17994.24	227343
08	0	7704	9659339	35235	211	38	191500	17994.24	188501
08	0	7705	9659339	35798	6	185	191500	17994.24	196766
08	0	7706	9659339	35798	0	321	191500	17994.24	217885
08	0	7707	9659339	35798	0	479	191500	17994.24	232673
08	0	7708	9659339	36028	1	222	191500	17994.24	228784
08	0	7709	9659339	36028	24	85	191500	17994.24	193313
08	0	7710	9790093	36028	343	0	191500	17994.24	197333
08	0	7711	9790093	36562	755	0	191500	17994.24	254554
08	0	7712	9790093	36562	1188	0	191500	17994.24	302345
08	0	7801	9790093	36562	1588	0	191500	17994.24	342594
08	0	7802	9790093	36562	1374	0	191500	17994.24	315481
08	1	7803	9790093	36687	955	3	191500	17994.24	260136
08	1	7804	9790093	36687	391	5	191500	17994.24	199700
08	1	7805	9790093	36687	166	75	191500	17994.24	208988
08	1	7806	9790093	36372	12	258	191500	17994.24	250650
08	1	7807	9790093	36372	0	305	191500	17994.24	264861
08	1	7808	9790093	36372	4	277	191500	17994.24	258043
08	1	7809	9790093	36095	45	204	191500	17994.24	139162

DATA FILE FOR OFFUTT AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
08	1	7810	9745897	36095	358	5	191500	17994.24	185363
08	1	7811	9745897	35590	779	0	191500	17994.24	231235
08	1	7812	9745897	35590	1249	0	191500	17994.24	283557
08	1	7901	9745897	35590	1708	0	191500	17994.24	374052
08	1	7902	9745897	35137	1410	0	191500	17994.24	310074
08	1	7903	9745897	35137	874	0	191500	17994.24	251931
08	1	7904	9745897	35137	511	0	191500	17994.24	201669
08	1	7905	9745897	34671	181	41	191500	17994.24	193612
08	1	7906	9745897	34671	25	185	191500	17994.24	193333
08	1	7907	9745897	34671	5	264	191500	17994.24	223744
08	1	7908	9745897	34053	8	319	191500	17994.24	226068
08	1	7909	9745897	34053	48	126	191500	17994.24	177542
08	1	7910	10070530	34053	373	5	191500	17994.24	186286
08	1	7911	10070530	34053	821	0	191500	17994.24	242890
08	1	7912	10070530	33321	1005	0	191500	17994.24	274815
08	1	8001	10070530	33321	1218	0	191500	17994.24	300324
08	1	8002	10070530	33321	1192	0	191500	17994.24	305359
08	1	8003	10070530	33590	936	0	191500	17994.24	268876
08	1	8004	10070530	33590	419	11	191500	17994.24	207119
08	1	8005	10070530	33288	136	68	191500	17994.24	172877
08	1	8006	10070530	33288	11	229	191500	17994.24	208674
08	1	8007	10070530	33288	0	452	191500	17994.24	233303
08	1	8008	10070530	33158	1	343	191500	17994.24	211636
08	1	8009	10070530	33158	84	132	191500	17994.24	197263
08	1	8010	10070530	33158	427	3	191500	17994.24	187029
08	1	8011	10070530	32744	656	0	191500	17994.24	215171
08	1	8012	10070530	32744	1121	0	191500	17994.24	294164
08	1	8101	10070530	32744	1194	0	191500	17994.24	281951
08	1	8102	10070530	32964	993	0	191500	17994.24	278479
08	1	8103	10070530	32964	724	0	191500	17994.24	233666
08	1	8104	10070530	32964	196	34	191500	17994.24	178710
08	1	8105	10070530	33091	155	52	191500	17994.24	170449
08	1	8106	10070530	33091	0	302	317600	21424.16	215344
08	1	8107	10070530	33091	3	385	317600	21424.16	226207
08	1	8108	10070530	33340	0	236	317600	21424.16	205179
08	1	8109	10070530	33340	53	123	317600	21424.16	204334
08	1	8110	10103847	33340	369	0	317600	21424.16	197324
08	1	8111	10103847	33550	636	0	317600	21424.16	227459
08	1	8112	10103847	33550	1150	0	317600	21424.16	287500
08	1	8201	10103847	33550	1586	0	317600	21424.16	351267
08	1	8202	10103847	33543	1102	0	326600	21424.16	292743
08	1	8203	10103847	33543	845	0	326600	21424.16	267000
08	1	8204	10103847	33543	497	3	326600	21424.16	220120
08	1	8205	10103847	33892	89	39	326600	21424.16	178729
08	1	8206	10103847	33892	39	114	326600	21424.16	219420
08	1	8207	10103847	33892	0	377	326600	21424.16	243030
08	1	8208	10103847	34061	10	263	428400	21424.16	219866
08	1	8209	10103847	34061	98	126	428400	21424.16	203230

DATA FILE FOR KELLY AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
09	9	7410	13362853	00000	0010	172	0000000	000000.00	231933
09	9	7411	13362853	0	221	43	0	0.00	243583
09	9	7412	13362853	0	403	7	0	0.00	234624
09	9	7501	13362853	0	327	35	0	0.00	268145
09	9	7502	13362853	0	298	3	0	0.00	252229
09	9	7503	13362853	0	141	60	0	0.00	247263
09	9	7504	13362853	0	27	167	0	0.00	229177
09	9	7505	13362853	0	0	297	0	0.00	235989
09	9	7506	13362853	0	0	453	0	0.00	258440
09	9	7507	13362853	0	0	536	0	0.00	266590
09	9	7508	13362853	0	0	537	0	0.00	264189
09	9	7509	13362853	0	1	340	0	0.00	246201
09	9	7510	13483950	0	17	215	0	0.00	226609
09	9	7511	13483950	0	200	82	0	0.00	235974
09	9	7512	13483950	0	392	26	0	0.00	255066
09	9	7601	13483950	0	466	1	0	0.00	291697
09	9	7602	13483950	0	180	44	0	0.00	231639
09	9	7603	13483950	0	148	106	0	0.00	258511
09	9	7604	13483950	0	16	84	0	0.00	220681
09	9	7605	13483950	0	17	142	0	0.00	218157
09	9	7606	13483950	0	0	468	0	0.00	233369
09	9	7607	13483950	0	0	486	0	0.00	228850
09	9	7608	13483950	0	0	590	0	0.00	247878
09	9	7609	13483950	21365	0	440	0	0.00	227975
09	9	7610	13498674	21259	112	64	0	0.00	203686
09	9	7611	13498674	20759	325	4	0	0.00	264342
09	9	7612	13498674	20327	517	0	0	0.00	275974
09	9	7701	13498674	20400	653	0	0	0.00	315509
09	9	7702	13498674	20440	282	2	0	0.00	231464
09	9	7703	13498674	21208	136	47	0	0.00	286524
09	9	7704	13498674	21060	30	97	0	0.00	206020
09	9	7705	13498674	21039	0	307	0	0.00	223125
09	9	7706	13498674	20171	0	491	0	0.00	249471
09	9	7707	13498674	20137	0	619	0	0.00	239030
09	9	7708	13498674	19961	0	654	0	0.00	279156
09	9	7709	13498674	20202	0	555	0	0.00	243487
09	9	7710	13912709	20861	19	222	123300	3612.69	213908
09	9	7711	13912709	20872	125	39	123300	3612.69	211068
09	9	7712	13912709	20849	337	9	123300	3612.69	240988
09	9	7801	13912709	20775	604	4	123300	3612.69	312879
09	9	7802	13912709	20772	484	9	123300	3612.69	287363
09	9	7803	13912709	20803	167	42	123300	3612.69	252871
09	9	7804	13912709	20921	15	210	123300	3612.69	197071
09	9	7805	13912709	20946	0	472	123300	3612.69	254101
09	9	7806	13912709	20970	0	581	123300	3612.69	267028
09	9	7807	13912709	20848	0	715	123300	3612.69	262685
09	9	7808	13912709	20819	0	572	123300	3612.69	278177
09	9	7809	13912709	20877	0	420	636400	40761.13	236462

DATA FILE FOR KELLY AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
09	0	7810	13702877	20409	3	185	636400	40761.13	204976
09	0	7811	13702877	20266	124	93	636400	40761.13	204975
09	0	7812	13702877	20120	356	13	636400	40761.13	229787
09	0	7901	13702877	19971	626	1	636400	40761.13	319314
09	0	7902	13702877	19836	349	14	636400	40761.13	255686
09	0	7903	13702877	19807	104	53	636400	40761.13	222431
09	0	7904	13702877	19766	23	151	1207400	40761.13	193534
09	0	7905	13702877	19766	1	302	1207400	40761.13	205167
09	0	7906	13702877	19584	0	418	1487500	102383.13	211580
09	0	7907	13702877	19512	0	541	1487500	102383.13	231795
09	0	7908	13702877	19427	0	533	1487500	102383.13	241797
09	0	7909	13702877	19608	0	370	1487500	102383.13	193880
09	0	7910	13718411	19663	24	279	1487500	102383.13	205143
09	0	7911	13718411	19658	259	37	1487500	102383.13	190964
09	0	7912	13718411	19382	338	10	1487500	102383.13	186199
09	0	8001	13718411	19312	359	11	1487500	102383.13	241057
09	0	8002	13718411	19235	331	16	1487500	102383.13	224410
09	0	8003	13718411	19078	138	83	1487500	102383.13	185070
09	0	8004	13718411	19190	25	188	1668200	102383.13	165624
09	0	8005	13718411	19759	0	353	1668200	102383.13	180767
09	0	8006	13718411	20256	0	649	1668200	102383.13	230786
09	0	8007	13718411	20238	0	730	1668200	102383.13	242680
09	0	8008	13718411	19895	0	641	1668200	102383.13	222551
09	0	8009	13718411	20073	0	553	1668200	102383.13	230789
09	1	8010	13874882	20019	52	249	2162200	127379.53	198743
09	1	8011	13874882	20019	227	33	2162200	127379.53	198291
09	1	8012	13874882	19964	266	26	2162200	127379.53	210979
09	1	8101	13874882	19750	334	3	2162200	127379.53	228517
09	1	8102	13874882	19679	258	40	2162200	127379.53	213276
09	1	8103	13874882	19791	102	56	2162200	127379.53	245777
09	1	8104	13874882	19806	0	285	2859600	127379.53	196023
09	1	8105	13874882	19843	0	396	2859600	127379.53	209017
09	1	8106	13874882	20095	0	497	2859600	127379.53	234624
09	1	8107	13874882	20347	0	593	2859600	127379.53	260339
09	1	8108	13874882	20286	0	588	2859600	127379.53	276406
09	1	8109	13874882	20122	4	400	2859600	127379.53	228759
09	1	8110	13875186	20404	60	230	2859600	127379.53	206724
09	1	8111	13875186	20492	133	32	2859600	127379.53	196828
09	1	8112	13875186	20324	377	1	2859600	127379.53	208452
09	1	8201	13875186	20307	394	32	2859600	127379.53	240084
09	1	8202	13875186	20307	359	13	2859600	127379.53	229710
09	1	8203	13875186	20290	114	169	2859600	127379.53	238875
09	1	8204	13875186	20558	50	212	2859600	127379.53	200399
09	1	8205	13875186	19347	0	324	2859600	127379.53	206193
09	1	8206	13875186	18135	0	549	2859600	127379.53	265868
09	1	8207	13875186	20938	0	665	2859600	127379.53	249921
09	1	8208	13875186	20815	0	667	2859600	127379.53	272856
09	1	8209	13875186	20691	0	470	2859600	127379.53	244389

DATA FILE FOR LANGLEY AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
10	0	7410	04884354	00000	0242	024	0000000	000000.00	122065
10	0	7411	4884354	0	408	028	0	0.00	116967
10	0	7412	4884354	0	604	0	0	0.00	177876
10	0	7501	4884354	9748	614	1	0	0.00	205488
10	0	7502	4884354	9748	565	4	0	0.00	169444
10	0	7503	4884354	9709	522	1	0	0.00	164566
10	0	7504	4884354	9709	363	19	0	0.00	144032
10	0	7505	4884354	9843	57	131	0	0.00	142256
10	0	7506	4884354	9843	0	325	0	0.00	125066
10	0	7507	4884354	9843	0	375	0	0.00	135488
10	0	7508	4884354	8268	0	444	0	0.00	147193
10	0	7509	4884354	8268	9	225	0	0.00	124927
10	0	7510	5699601	8268	110	56	0	0.00	106657
10	0	7511	5699601	8497	296	12	0	0.00	131552
10	0	7512	5699601	8497	664	0	0	0.00	191638
10	0	7601	5699601	9021	821	0	0	0.00	231350
10	0	7602	5699601	9021	428	8	0	0.00	198436
10	0	7603	5699601	9068	378	10	0	0.00	148834
10	0	7604	5699601	9068	226	69	6500	0.00	145545
10	0	7605	5699601	9496	79	86	6500	0.00	120120
10	0	7606	5699601	9496	10	288	6500	0.00	147721
10	0	7607	5699601	9496	0	422	6500	0.00	157413
10	0	7608	5699601	9958	0	352	6500	0.00	140561
10	0	7609	5699601	9958	13	143	6500	0.00	136948
10	0	7610	5972847	9958	322	10	6500	0.00	127943
10	0	7611	5972847	10081	650	0	6500	0.00	188649
10	0	7612	5972847	10081	801	0	6500	0.00	225370
10	0	7701	5972847	10111	1118	0	6500	0.00	267369
10	0	7702	5972847	10111	650	0	6500	0.00	192917
10	0	7703	5972847	10137	306	14	6500	23160.76	160417
10	0	7704	5972847	10137	151	53	21700	23160.76	136494
10	0	7705	5972847	10173	39	138	21700	23160.76	114946
10	0	7706	5972847	10173	3	294	21700	23160.76	131667
10	0	7707	5972847	10173	0	506	21700	23160.76	149247
10	0	7708	5972847	10211	0	491	21700	23160.76	170044
10	0	7709	5972847	10211	0	356	21700	23160.76	136493
10	0	7710	6166176	10211	135	36	21700	23160.76	123298
10	0	7711	6166176	10122	314	25	21700	23160.76	143419
10	0	7712	6166176	10122	659	0	21700	23160.76	209268
10	0	7801	6166176	10130	854	0	21700	23160.76	224378
10	0	7802	6166176	10130	956	0	21700	23160.76	218001
10	0	7803	6166176	10128	624	0	457900	23160.76	234080
10	0	7804	6166176	10128	244	8	457900	23160.76	121973
10	0	7805	6166176	10526	95	98	457900	23160.76	132540
10	0	7806	6166176	10526	0	311	457900	23160.76	134442
10	0	7807	6166176	10526	0	374	457900	23160.76	146237
10	0	7808	6166176	10416	0	562	457900	23160.76	159504
10	0	7809	6166176	10416	9	257	457900	23160.76	138149

DATA FILE FOR LANGLEY AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
10	1	7810	6197336	10416	187	23	711300	23160.76	115414
10	1	7811	6197336	10628	256	3	711300	23160.76	121120
10	1	7812	6197336	10628	626	3	711300	23160.76	185960
10	1	7901	6197336	10618	804	0	711300	23160.76	209111
10	1	7902	6197336	10618	872	0	711300	23160.76	191037
10	1	7903	6197336	10666	473	16	711300	23160.76	261792
10	1	7904	6197336	10666	234	5	979500	30268.06	130735
10	1	7905	6197336	10680	37	113	979500	30268.06	118012
10	1	7906	6197336	10680	5	198	995300	30268.06	103626
10	1	7907	6197336	10680	0	407	995300	30268.06	142094
10	1	7908	6197336	10588	0	429	995300	30268.06	153786
10	1	7909	6197336	10588	5	207	995300	30268.06	124911
10	1	7910	6197336	10588	218	46	995300	30268.06	121322
10	1	7911	6197336	11782	313	12	995300	30268.06	150552
10	1	7912	6197336	11782	688	0	995300	30268.06	177009
10	1	8001	6197336	12014	825	0	995300	30268.06	208338
10	1	8002	6197336	10698	847	0	995300	30268.06	237627
10	1	8003	6197336	10698	518	0	995300	30268.06	184567
10	1	8004	6197336	10813	159	18	995300	30268.06	131046
10	1	8005	6197336	10813	46	173	995300	30268.06	115198
10	1	8006	6197336	10813	4	283	995300	30268.06	128929
10	1	8007	6197336	10813	0	531	995300	30268.06	133822
10	1	8008	6197336	10813	0	529	995300	30268.06	157490
10	1	8009	6197336	10813	5	334	995300	30268.06	139152
10	1	8010	6313411	10813	157	56	995300	30268.06	117835
10	1	8011	6313411	10813	472	0	995300	30268.06	151482
10	1	8012	6313411	10813	702	0	995300	30268.06	210213
10	1	8101	6313411	11056	1000	0	995300	30268.06	233177
10	1	8102	6313411	11056	619	0	995300	30268.06	202311
10	1	8103	6313411	11056	597	0	995300	30268.06	137437
10	1	8104	6313411	11056	157	38	995300	30268.06	125966
10	1	8105	6313411	11056	79	124	995300	30268.06	125103
10	1	8106	6313411	11056	0	440	995300	30268.06	105988
10	1	8107	6313411	11056	0	503	995300	30268.06	155407
10	1	8108	6313411	11056	0	342	995300	30268.06	155407
10	1	8109	6313411	0	11	212	995300	30268.06	119943
10	1	8110	6372109	0	182	27	995300	30268.06	110081
10	1	8111	6372109	0	446	0	995300	30268.06	170129
10	1	8112	6372109	0	775	0	995300	30268.06	193079
10	1	8201	6372109	0	928	0	995300	30268.06	243515
10	1	8202	6372109	0	717	0	995300	30268.06	200820
10	1	8203	6372109	0	612	0	995300	30268.06	209284
10	1	8204	6372109	0	319	7	995300	30268.06	153252
10	1	8205	6372109	0	24	162	995300	30268.06	115325
10	1	8206	6372109	0	0	198	995300	30268.06	106618
10	1	8207	6372109	0	0	361	995300	30268.06	152348
10	1	8208	6372109	0	2	294	995300	30268.06	143393
10	1	8209	6372109	0	0	195	995300	30268.06	158495

DATA FILE FOR MOUNTAIN HOME AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
11	0	7410	04167902	00000	0429	000	0000000	000000.00	082658
11	0	7411	4167902	0	720	0	0	0.00	101648
11	0	7412	4167902	4145	976	0	0	0.00	115210
11	0	7501	4167902	4145	1129	0	0	0.00	140572
11	0	7502	4167902	4145	831	0	0	0.00	122654
11	0	7503	4167902	4145	736	0	0	0.00	105745
11	0	7504	4167902	4145	615	0	0	0.00	105061
11	0	7505	4167902	4109	240	15	0	0.00	73319
11	0	7506	4167902	4109	50	95	0	0.00	71489
11	0	7507	4167902	4109	1	505	0	0.00	66988
11	0	7508	4167902	4267	24	174	0	0.00	70220
11	0	7509	4167902	4267	79	79	0	0.00	65328
11	0	7510	4254078	4267	432	7	0	0.00	86236
11	0	7511	4254078	4351	816	0	0	0.00	113497
11	0	7512	4254078	4351	1021	0	0	0.00	128673
11	0	7601	4254078	4238	1089	0	0	0.00	130955
11	0	7602	4254078	4238	921	0	0	0.00	131882
11	0	7603	4254078	4249	914	0	0	0.00	115758
11	0	7604	4254078	4249	508	0	0	0.00	103092
11	0	7605	4254078	4281	157	16	0	0.00	75756
11	0	7606	4254078	4281	97	85	0	0.00	64945
11	0	7607	4254078	4281	1	343	0	0.00	67702
11	0	7608	4254078	4313	29	155	0	0.00	86587
11	0	7609	4254078	4313	75	61	0	0.00	66700
11	0	7610	4183558	4313	450	1	0	0.00	77282
11	0	7611	4183558	4270	763	0	0	0.00	107117
11	0	7612	4183558	4270	1133	0	0	0.00	130285
11	0	7701	4183558	4272	1352	0	0	0.00	135441
11	0	7702	4183558	4272	850	0	0	0.00	121439
11	0	7703	4183558	4269	799	0	0	0.00	100683
11	0	7704	4183558	4269	293	31	0	0.00	90406
11	0	7705	4183558	4569	346	10	0	0.00	63408
11	0	7706	4183558	4569	13	203	0	0.00	64268
11	0	7707	4183558	4569	6	249	0	0.00	64428
11	0	7708	4183558	4801	39	290	0	0.00	71315
11	0	7709	4183558	4801	157	45	0	0.00	66197
11	0	7710	4261433	4801	409	0	0	0.00	83858
11	0	7711	4261433	4432	759	0	307200	0.00	101799
11	0	7712	4261433	4432	928	0	307200	0.00	110348
11	0	7801	4261433	4773	903	0	307200	0.00	126568
11	0	7802	4261433	4773	817	0	307200	0.00	107136
11	0	7803	4261433	4776	514	0	307200	0.00	98291
11	0	7804	4261433	4776	456	0	335000	0.00	89370
11	0	7805	4261433	4751	298	5	335000	0.00	81348
11	0	7806	4261433	4751	63	84	335000	0.00	67022
11	0	7807	4261433	4751	4	286	335000	0.00	63901
11	0	7808	4261433	4714	36	236	335000	0.00	76484
11	0	7809	4261433	4714	165	72	335000	0.00	75193

DATA FILE FOR MOUNTAIN HOME AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
11	1	7810	4277465	4714	363	0	335000	0.00	77880
11	1	7811	4277465	4578	882	0	335000	0.00	106294
11	1	7812	4277465	4578	1212	0	335000	0.00	132896
11	1	7901	4277465	4575	1445	0	335000	0.00	143707
11	1	7902	4277465	4575	827	0	335000	0.00	125626
11	1	7903	4277465	4609	696	0	335000	0.00	104747
11	1	7904	4277465	4609	553	0	377200	0.00	88295
11	1	7905	4277465	4579	250	16	377200	0.00	62200
11	1	7906	4277465	4579	140	116	377200	0.00	65933
11	1	7907	4277465	4579	1	350	377200	0.00	70587
11	1	7908	4277465	4602	5	243	377200	0.00	68376
11	1	7909	4277465	4602	24	103	377200	0.00	66301
11	1	7910	4277465	4602	328	6	377200	0.00	70722
11	1	7911	4277465	4564	877	0	377200	0.00	102716
11	1	7912	4277465	4564	908	0	377200	0.00	124038
11	1	8001	4277465	4568	1065	0	377200	0.00	127349
11	1	8002	4277465	4621	756	0	377200	0.00	112448
11	1	8003	4277465	4621	744	0	377200	0.00	98694
11	1	8004	4277465	4699	426	0	377200	0.00	87525
11	1	8005	4277465	4699	305	18	377200	0.00	63372
11	1	8006	4277465	4699	145	63	377200	0.00	70568
11	1	8007	4277465	4699	1	246	377200	0.00	63939
11	1	8008	4277465	4699	39	121	377200	0.00	72051
11	1	8009	4277465	4699	118	32	377200	0.00	64507
11	1	8010	4309111	4699	422	0	377200	0.00	73052
11	1	8011	4309111	4699	778	0	377200	0.00	104586
11	1	8012	4309111	4699	1025	0	377200	0.00	122007
11	1	8101	4309111	4703	999	0	377200	0.00	119461
11	1	8102	4309111	4703	786	0	377200	0.00	111723
11	1	8103	4309111	4706	663	0	409100	0.00	97836
11	1	8104	4309111	4706	479	0	588200	0.00	87642
11	1	8105	4309111	4706	341	2	853400	0.00	78619
11	1	8106	4309111	4706	107	62	878200	0.00	63289
11	1	8107	4309111	4706	14	306	1182800	0.00	70325
11	1	8108	4309111	4706	2	374	1182800	0.00	81458
11	1	8109	4309111	4966	117	121	1182800	0.00	82229
11	1	8110	4319334	4966	480	0	1182800	0.00	78736
11	1	8111	4319334	4966	628	0	1182800	0.00	94889
11	1	8112	4319334	4966	910	0	1182800	0.00	125371
11	1	8201	4319334	4355	1252	0	1182800	0.00	135873
11	1	8202	4319334	4355	999	0	1182800	0.00	121888
11	1	8203	4319334	4355	742	0	1271800	0.00	110422
11	1	8204	4319334	4355	601	0	1271800	0.00	88804
11	1	8205	4319334	4119	318	2	1271800	0.00	77176
11	1	8206	4319334	4119	85	132	1324900	0.00	78918
11	1	8207	4319334	4119	15	258	1346900	0.00	70170
11	1	8208	4319334	4093	0	315	1346900	0.00	80447
11	1	8209	4319334	4093	161	66	1346900	0.00	78934

DATA FILE FOR ELLSWORTH AFB

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
12	0	7410	05864054	00000	0341	004	0000000	000000.00	129751
12	0	7411	5864054	0	781	0	0	0.00	164587
12	0	7412	5864054	0	1064	0	0	0.00	197258
12	0	7501	5864054	0	1222	0	0	0.00	224098
12	0	7502	5864054	0	1304	0	0	0.00	232568
12	0	7503	5864054	0	1139	0	0	0.00	211299
12	0	7504	5864054	0	711	0	0	0.00	173680
12	0	7505	5864054	0	303	13	0	0.00	126852
12	0	7506	5864054	0	89	66	0	0.00	101950
12	0	7507	5864054	0	0	379	0	0.00	91711
12	0	7508	5864054	0	9	244	0	0.00	97123
12	0	7509	5864054	0	187	21	0	0.00	105592
12	0	7510	5457026	0	499	21	0	0.00	136737
12	0	7511	5457026	0	942	0	0	0.00	183078
12	0	7512	5457026	0	1089	0	0	0.00	214612
12	0	7601	5457026	0	1278	0	0	0.00	244164
12	0	7602	5457026	0	895	0	0	0.00	194840
12	0	7603	5457026	0	980	0	0	0.00	204414
12	0	7604	5457026	0	533	0	0	0.00	159236
12	0	7605	5457026	0	306	3	0	0.00	127375
12	0	7606	5457026	0	96	86	0	0.00	107843
12	0	7607	5457026	0	1	283	27100	1571.80	90703
12	0	7608	5457026	15494	4	279	27100	1571.80	95500
12	0	7609	5457026	15494	116	106	27100	1571.80	93430
12	0	7610	5775567	15494	585	6	27100	1571.80	147125
12	0	7611	5775567	14417	961	0	27100	1571.80	182555
12	0	7612	5775567	14417	1138	0	27100	1571.80	219843
12	0	7701	5775567	14417	1595	0	27100	1571.80	251974
12	0	7702	5775567	14688	839	0	27100	1571.80	181580
12	0	7703	5775567	14688	872	0	27100	1571.80	181503
12	0	7704	5775567	14688	494	0	27100	1571.80	138242
12	0	7705	5775567	15002	157	37	27100	1571.80	113995
12	0	7706	5775567	15002	7	174	27100	1571.80	98210
12	0	7707	5775567	15002	0	318	27100	1571.80	92150
12	0	7708	5775567	15645	33	111	27100	1571.80	98909
12	0	7709	5775567	15645	135	67	27100	1571.80	107553
12	0	7710	5723674	15645	448	0	27100	1571.80	139858
12	0	7711	5723674	16499	958	0	27100	1571.80	194507
12	0	7712	5723674	16499	1387	0	27100	1571.80	235396
12	0	7801	5723674	16499	1725	0	27100	1571.80	252311
12	0	7802	5723674	16499	1443	0	27100	1571.80	238678
12	0	7803	5723674	16629	897	0	27100	1571.80	200044
12	0	7804	5723674	16629	559	0	27100	1571.80	145215
12	0	7805	5723674	16629	289	14	27100	1571.80	125446
12	0	7806	5723674	16378	103	89	27100	1571.80	94265
12	0	7807	5723674	16378	22	211	27100	1571.80	107102
12	0	7808	5723674	16378	33	210	27100	1571.80	99166
12	0	7809	5723674	16215	111	172	27100	1571.80	111150

DATA FILE FOR ELLSWORTH AFB CONTINUED

BA	PD	YM	AREA	POP	HD	CD	DPRJ	EPRJ	NRGY
12	1	7810	5669201	16215	425	0	27100	1571.80	136279
12	1	7811	5669201	15862	1063	0	27100	1571.80	198977
12	1	7812	5669201	15862	1428	0	27100	1571.80	213263
12	1	7901	5669201	15862	1781	0	27100	1571.80	280578
12	1	7902	5669201	15537	1401	0	27100	1571.80	229530
12	1	7903	5669201	15537	960	0	27100	1571.80	203625
12	1	7904	5669201	15537	670	1	27100	1571.80	164482
12	1	7905	5669201	15200	408	9	27100	1571.80	126548
12	1	7906	5669201	15200	99	90	27100	1571.80	94163
12	1	7907	5669201	15200	8	163	27100	1571.80	94879
12	1	7908	5669201	14899	40	132	27100	1571.80	96685
12	1	7909	5669201	14899	81	107	27100	1571.80	92379
12	1	7910	6208945	14899	445	3	27100	1571.80	123314
12	1	7911	6208945	14899	994	0	27100	1571.80	172215
12	1	7912	6208945	14554	991	0	27100	1571.80	175851
12	1	8001	6208945	14554	1399	0	27100	1571.80	216209
12	1	8002	6208945	14554	1122	0	27100	1571.80	194522
12	1	8003	6208945	14470	1079	0	27100	1571.80	179530
12	1	8004	6208945	14470	518	6	27100	1571.80	142362
12	1	8005	6208945	14253	250	30	27100	1571.80	113111
12	1	8006	6208945	14253	51	142	27100	1571.80	96868
12	1	8007	6208945	14253	0	385	27100	1571.80	102886
12	1	8008	6208945	14078	14	183	27100	1571.80	104159
12	1	8009	6208945	14078	135	74	27100	1571.80	107286
12	1	8010	5676868	14078	486	15	27100	1571.80	131164
12	1	8011	5676868	14042	704	0	27100	1571.80	153308
12	1	8012	5676868	14042	989	0	27100	1571.80	198835
12	1	8101	5676868	14042	985	0	27100	1571.80	185454
12	1	8102	5676868	14237	989	0	27100	1571.80	189424
12	1	8103	5676868	14237	804	0	27100	1571.80	123034
12	1	8104	5676868	14237	390	3	27100	1571.80	166084
12	1	8105	5676868	14150	329	2	27100	1571.80	109233
12	1	8106	5676868	14150	69	64	27100	1571.80	87663
12	1	8107	5676868	14150	23	271	27100	1571.80	90842
12	1	8108	5676868	14029	8	191	27100	1571.80	92817
12	1	8109	5676868	14029	113	82	27100	1571.80	96477
12	1	8110	5675432	14029	541	1	27100	1571.80	128310
12	1	8111	5675432	14119	702	0	216800	1571.80	151907
12	1	8112	5675432	14119	1151	0	223000	1571.80	191062
12	1	8201	5675432	14119	1537	0	223000	1571.80	236009
12	1	8202	5675432	14554	1168	0	223000	1571.80	199274
12	1	8203	5675432	14554	1058	0	223000	1571.80	185569
12	1	8204	5675432	14554	721	0	223000	1571.80	160168
12	1	8205	5675432	14653	426	2	223000	1571.80	118550
12	1	8206	5675432	14653	195	18	223000	1571.80	98283
12	1	8207	5675432	14653	3	212	223000	1571.80	85739
12	1	8208	5675432	14401	28	167	243500	1571.80	108658
12	1	8209	5675432	14401	224	37	243500	1571.80	101238

APPENDIX B

SAMPLE OUTPUT FOR LACKLAND AFB

This appendix contains sample output for Lackland AFB from the Regression and T-test subprograms of the Statistical Package for the Social Sciences (SPSS). The FORTRAN program used to compute the predicted energy consumption data is also included. The following sections of output are inclused in the order listed:

1. Control period regression run with all variables included.

2. Control period regression run with only the variables that were significant in the above run.

3. Scattergram plot of residuals versus the regression model Y values for the second run above.

4. FORTRAN program to compute monthly predicted energy consumption values. This used the MLR model coefficients developed in #2 above and operated on the data in the test period.

5. Matched-Pairs T-test to compare predicted and actual energy consumption values in the test period.

6. Eight-year period regression run with all variables included.

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VOGELBACK COMPUTING CENTER
NORTHWESTERN UNIVERSITY

S P S S - - STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES

VERSION 8.0 -- JUNE 18, 1979

* 1. NOTE:  CONTROL PERIOD REGRESSION RUN WITH ALL VARIABLES. *

RUN NAME        REGRESS LACD
FILE NAME       REGLAC
VARIABLE LIST   BA,PD,YM,AREA,POP,HD,CD,DPRJ,EPRJ,NRGY
INPUT FORMAT    FREEFIELD
MISSING VALUES  POP(0)
SELECT IF       (PD EQ 0)
REGRESSION      METHOD=STEPWISE/VARIABLES=AREA,POP,HD,CD,DPRJ,NRGY/
                REGRESSION=NRGY WITH AREA,POP,HD,CD,DPRJ/RESIDUALS
OPTIONS         2,11
STATISTICS      ALL

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

VARIABLE             MEAN     STANDARD DEV     CASES

AREA         9705551.2545      167245.9083        55
POP            30650.5217        1957.5157        46
HD               150.0909         191.9357        55
CD               217.8000         225.3235        55
DPRJ                    0                0        55
NRGY          201012.3455       35766.6066        55


CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

POP          -.75908
HD            .13749   -.31067
CD           -.03027    .41151   -.69435
DPRJ         99.00000  99.00000  99.00000  99.00000
NRGY         -.02163    .35891   -.01957    .60537  99.00000

              AREA       POP        HD         CD         DPRJ

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *
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DEP. VAR... NRGY

MEAN RESPONSE   201012.34545      STD. DEV.   35766.60655

VARIABLE DPRJ     IS A CONSTANT.  INCLUSION LEVEL SET TO ZERO.

VARIABLE(S) ENTERED ON STEP   1
CD

MULTIPLE R     .6054 ANOVA          DF  SUM SQUARES  MEAN SQ.      F
R SQUARE       .3665 REGRESSION     1.    .2109E+11   .21E+11    25.453
STD DEV  28789.8710 RESIDUAL      44.    .3646E+11   .82E+09 SIG. .000
ADJ R SQUARE  .3521 COEFF OF VARIABILITY    14.3PCT

VARIABLE        B       S.E. B        F      SIG.      BETA   ELASTICITY

CD            96.093    19.047    25.453  .000      .60537    .10412
CONSTANT 180083.225  5935.333   920.569     0

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP   2
HD

MULTIPLE R     .8226 ANOVA          DF  SUM SQUARES  MEAN SQ.      F
R SQUARE       .6766 REGRESSION     2.    .3895E+11   .19E+11    44.984
STD DEV  20807.1003 RESIDUAL      43.    .1861E+11   .43E+09 SIG. .000
ADJ R SQUARE  .6616 COEFF OF VARIABILITY    10.4PCT

VARIABLE        B       S.E. B        F      SIG.      BETA   ELASTICITY

CD           181.386    19.129    89.916     0     1.14270    .19653
HD           144.206    22.456    41.238     0      .77386    .10768
CONSTANT 139862.474  7591.383   339.438     0

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *
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* NOTE: THE FOLLOWING TWO REGRESSION STEPS WERE NOT UTILIZED BECAUSE THE VARIABLES THAT ENTERED WERE NOT SIGNIFICANT. *

DEP. VAR... NRGY

VARIABLE(S) ENTERED ON STEP 3
POP

MULTIPLE R	.8347	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.6967	REGRESSION	3.	.4010E+11	.13E+11	32.159
STD DEV	20388.9428	RESIDUAL	42.	.1745E+11	.41E+09	SIG. .000
ADJ R SQUARE	.6750	COEFF OF VARIABILITY		10.1PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	172.046	19.563	77.344	.000	1.08386	.18641
HD	145.603	22.021	43.719	.000	.78135	.10872
POP	2.844	1.705	2.782	.103	.15563	.43358
CONSTANT	54532.254	51698.500	1.113	.298		

* *

VARIABLE(S) ENTERED ON STEP 4
AREA

MULTIPLE R	.8356	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.6982	REGRESSION	4.	.4019E+11	.10E+11	23.718
STD DEV	20583.6111	RESIDUAL	41.	.1737E+11	.42E+09	SIG. .000
ADJ R SQUARE	.6688	COEFF OF VARIABILITY		10.2PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	166.865	22.766	53.724	0	1.05122	.18080
HD	143.217	22.834	39.337	0	.76855	.10694
POP	3.993	3.045	1.720	.197	.21852	.60879
AREA	.015	.033	.209	.650	.07040	.72690
CONSTANT	-.125E+06	.39E+06	.100	.754		

ALL VARIABLES ARE IN THE EQUATION.

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	95 PCT C.I.	
CD	166.8649	120.8885	212.8413
HD	143.2165	97.1013	189.3317
POP	3.9926	-2.1563	10.1415
AREA	.0151	-.0514	.0815
CONSTANT	-.1E+06	-.9E+06	.6E+06

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

AREA	.00108			
POP	.08264	9.27009		
HD	-.17160	-11.64343	521.41407	
CD	-.37262	-38.17081	346.16650	518.28052
	AREA	POP	HD	CD

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

SUMMARY TABLE.

STEP	VARIABLE	E/R	F	MULT-R	R-SQ	CHANGE	R	OVERALL F	SIG.
1	CD	E	25.453	.605	.366	.366	.605	25.453	.000
2	HD	E	41.238	.823	.677	.310	-.020	44.984	.000
3	POP	E	2.782	.835	.697	.020	.359	32.159	.000
4	AREA	E	.209	.836	.698	.002	-.022	23.718	.000

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

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* 2. NOTE:  CONTROL PERIOD REGRESSION RUN WITH
          SIGNIFICANT VARIABLES ONLY. *

RUN NAME       REGRESS LACD
FILE NAME      REGLAC
VARIABLE LIST  BA,PD,YM,AREA,POP,HD,CD,DPRJ,EPRJ,NRGY
INPUT FORMAT   FREEFIELD
MISSING VALUES POP(0)
SELECT IF      (PD EQ 0)
REGRESSION     METHOD=STEPWISE/VARIABLES=HD,CD,NRGY/
               REGRESSION=NRGY WITH HD,CD/RESIDUALS
OPTIONS        2,11
STATISTICS     ALL

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

VARIABLE            MEAN     STANDARD DEV     CASES

HD              150.0909         191.9357        55
CD              217.8000         225.3235        55
NRGY         201012.3455       35766.6066        55


CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

CD            -.69435
NRGY          -.01957    .60537

                HD        CD

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

MEAN RESPONSE   201012.34545      STD. DEV.   35766.60655

VARIABLE(S) ENTERED ON STEP   1
CD

MULTIPLE R     .6054 ANOVA          DF  SUM SQUARES  MEAN SQ.      F
R SQUARE       .3665 REGRESSION      1.   .2531E+11   .25E+11   30.659
STD DEV  28735.4991 RESIDUAL       53.   .4376E+11   .82E+09 SIG. .000
ADJ R SQUARE   .3545 COEFF OF VARIABILITY     14.3PCT

VARIABLE        B       S.E. B       F     SIG.      BETA   ELASTICITY

CD           96.093    17.355    30.659  .000      .60537    .10412
CONSTANT 180083.225  5412.987  1106.809     0
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* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP   2
HD

MULTIPLE R     .8226 ANOVA          DF  SUM SQUARES  MEAN SQ.       F
R SQUARE       .6766 REGRESSION     2.   .4674E+11   .23E+11     54.399
STD DEV  20726.9185 RESIDUAL       52.   .2233E+11   .42E+09 SIG. .000
ADJ R SQUARE  .6642 COEFF OF VARIABILITY    10.3PCT

VARIABLE        B       S.E. B        F      SIG.      BETA   ELASTICITY

CD          181.386    17.395   108.736  .000     1.14270    .19653
HD          144.206    20.421    49.869  .000      .77386    .10768
CONSTANT 139862.474  6905.298   410.240     0

ALL VARIABLES ARE IN THE EQUATION.


COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE        B           95 PCT C.I.

CD          181.3857    146.4808  216.2907
HD          144.2063    103.2295  185.1831
CONSTANT      .1E+06      .1E+06    .1E+06

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

HD         416.99817
CD         246.63824 302.57469

            HD        CD

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

SUMMARY TABLE.

STEP VARIABLE E/R      F    MULT-R R-SQ CHANGE    R   OVERALL F  SIG.

  1  CD        E     30.659  .605  .366  .366  .605    30.659  .000
  2  HD        E     49.869  .823  .677  .310 -.020    54.399  .000

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *
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RESIDUAL PLOT.

Y VALUE	Y EST.	RESIDUAL	-2SD	0.0	+2SD
.17E+06	.17E+06	6382.115		I	
.18E+06	.17E+06	4886.343		I	
.20E+06	.19E+06	6056.680		I	
.19E+06	.19E+06	4178.560		I	
.18E+06	.18E+06	1805.887		I	
.19E+06	.17E+06	24780.291		I	
.17E+06	.17E+06	410.537		I	
.20E+06	.19E+06	14239.961		I	
.23E+06	.22E+06	11133.785		I	
.24E+06	.23E+06	7078.769		I	
.25E+06	.23E+06	17289.383		I	
.21E+06	.20E+06	12926.168		I	
.19E+06	.18E+06	15631.084		I	
.19E+06	.18E+06	11040.632		I	
.21E+06	.20E+06	11338.621		I	
.21E+06	.20E+06	7306.997		I	
.15E+06	.17E+06	-.17E+05		I	
.16E+06	.18E+06	-.17E+05		I	
.14E+06	.15E+06	-.15E+05		I	
.16E+06	.16E+06	-2418.757		I	
.21E+06	.22E+06	-.10E+05		I	
.22E+06	.22E+06	-2684.944		I	
.23E+06	.24E+06	-.11E+05		I	
.21E+06	.21E+06	-4337.200		I	
.18E+06	.16E+06	13145.731		I	
.19E+06	.18E+06	8656.930		I	
.21E+06	.21E+06	-4350.139		I	
.23E+06	.23E+06	509.802		I	
.17E+06	.18E+06	-3282.427		I	
.17E+06	.16E+06	5928.337		I	
.13E+06	.16E+06	-.23E+05		I	
.19E+06	.19E+06	2155.103		I	
.23E+06	.22E+06	3799.127		I	
.24E+06	.25E+06	-.10E+05		I	
.24E+06	.25E+06	-.16E+05		I	
.22E+06	.24E+06	-.10E+05		I	
.17E+06	.18E+06	-.10E+05		I	
.15E+06	.16E+06	-5656.307		I	
.18E+06	.19E+06	-7535.474		I	
.22E+06	.22E+06	-6055.632		I	
.19E+06	.21E+06	-.16E+05		I	
.17E+06	.17E+06	1787.870		I	
.13E+06	.18E+06	-.43E+05	R	I	
.21E+06	.22E+06	-.10E+05		I	
.22E+06	.24E+06	-.18E+05		I	
.25E+06	.26E+06	-.17E+05		I	
.24E+06	.24E+06	4726.882		I	
.33E+06	.21E+06	.11E+06		I	R

```
 .16E+06    .17E+06 -8255.455                    .    I
 .16E+06    .17E+06 -9339.931                   .     I
 .19E+06    .19E+06   330.063                         I.
 .23E+06    .23E+06  3586.987                         I .
 .18E+06    .19E+06 -3043.879                       . I
 .17E+06    .16E+06 11184.625                         I     .
 .14E+06    .17E+06  -.20E+05              .          I
```

```
NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
       R INDICATES POINT OUT OF RANGE OF PLOT

NUMBER OF CASES PLOTTED        55.
NUMBER OF 2 S.D. OUTLIERS       2. OR   3.64 PERCENT OF THE TOTAL

VON NEUMANN RATIO    1.77920          DURBIN-WATSON TEST    1.74685

NUMBER OF POSITIVE RESIDUALS     28.
NUMBER OF NEGATIVE RESIDUALS     27.
NUMBER OF RUNS OF SIGNS          18.

EXPECTED NUMBER OF RUNS OF SIGNS          28.
EXPECTED S.D. OF RUN DISTRIBUTION       3.67237
UNIT NORMAL DEVIATE-
  Z=(EXPECTED-OBSERVED)/S.D.           -2.72056
PROBABILITY OF OBTAINING .GE. ABS(Z)     .00326

RESIDUALS -         55 CASES WRITTEN ON FILE BCDOUT


* 3. NOTE:  PROGRAM AND SCATTERGRAM PLOT OF RESIDUALS FROM
          ABOVE REGRESSION RUN. *

RUN NAME       SCATTERGRAM OF RESIDUAL
FILE NAME      RESID
VARIABLE LIST  Y,YHAT,RESIDUAL
INPUT FORMAT   FIXED(26X,2F18.7,F15.7)

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

         VARIABLE  FORMAT  RECORD    COLUMNS

         Y         F18. 7       1    27-  44
         YHAT      F18. 7       1    45-  62
         RESIDUAL  F15. 7       1    63-  77

THE INPUT FORMAT PROVIDES FOR   3 VARIABLES.    3 WILL BE READ.
IT PROVIDES FOR  1 RECORDS (*CARDS*) PER CASE.
A MAXIMUM OF    77 *COLUMNS* ARE USED ON A RECORD.

WARNING - A NUMERIC VARIABLE HAS A WIDTH GREATER THAN 14.
SMALL ROUNDING/TRUNCATION ERRORS MAY OCCUR.
```

SCATTERGRAM   YHAT WITH RESIDUAL

SCATTERGRAM OF   (DOWN) YHAT
                  (ACROSS) RESIDUAL

```
            -25875.12   9895.79  45666.69  81437.60 117208.50
            .+----+----+----+----+----+----+----+----+----+.
  269553.30 +       *       I              I               +   269553.30
            I               I              I               I
            I               I              I               I
            I               I              I               I
            I               I              I               I
  257092.51 +        *      I              I               +   257092.51
            I               I              I               I
            I         *     I              I               I
            I               I              I               I
            I               I              I               I
  244631.72 +       * *     I              I               +   244631.72
            I              *I              I               I
            I         *     I              I               I
            I               I *            I               I
            I              *I              I               I
  232170.93 +------------*---------------------------------+   232170.93
            I             * I              I               I
            I           2 * I              I               I
            I         2     I              I               I
            I               I              I               I
  219710.14 +               *              I               +   219710.14
            I           *   I              I               I
            I               I              I              *I
            I           *   I              I               I
            I        *      I              I               I
  207249.36 +               I              I               +   207249.36
            I              *I              I               I
            I               I              I               I
            I               **             I               I
            I              *I              I               I
  194788.57 +-------------*--------------------------------+   194788.57
            I           *** I*             I               I
            I          *    I              I               I
            I               *              I               I
            I               I              I               I
  182327.78 +         *   * *              I               +   182327.78
            I*      *   *   I *            I               I
            I              *I              I               I
            I               I              I               I
            I       *  2 * *I              I               I
  169866.99 +      *      * I   *          I               +   169866.99
            I            * *I*             I               I
            I           *   I              I               I
            I               *              I               I
```

```
                I      *      I             I             I
157406.20  +              *     I             I             +  157406.20
           .+----+----+----+----+----+----+----+----+----+.
     -43760.57  -7989.67  27781.24  63552.14  99323.05

PLOTTED VALUES -   55   EXCLUDED VALUES -    0   MISSING  VALUES -    0
```

* 4. NOTE: FORTRAN PROGRAM TO CALCULATE PREDICTED ENERGY VALUES USING THE ABOVE REGRESSION MODEL AND THE DATA FROM THE TEST PERIOD. *

```
      PROGRAM ENERGY
C     COEF'S FROM PD0, OPERATE ON PD1
      INTEGER BA,PD,YM,AREA,POP,HD,CD,DPRJ,NRGY,I
      REAL CONST,BAREA,BPOP,BHD,BCD,BDPRJ,BEPRJ,EPRJ,CNRGY
      CONST=139862.474
      BHD=144.206
      BCD=181.386
      REWIND 10
      DO 10 I=1,96
         READ(10,*) BA,PD,YM,AREA,POP,HD,CD,DPRJ,EPRJ,NRGY
         IF(PD.EQ.1)THEN
            CNRGY=CONST+BHD*HD+BCD*CD
            WRITE(11,*)CNRGY,NRGY
         END IF
 10   CONTINUE
      STOP
      END
```

* 5. NOTE: T-TEST COMPARISON OF PREDICTED AND ACTUAL ENERGY VALUES FROM TEST PERIOD. *

```
RUN NAME        T-TEST LACD PD1 FROM PD0
FILE NAME       TTEST
VARIABLE LIST   CNRGY,NRGY
INPUT FORMAT    FREEFIELD
T-TEST          PAIRS=CNRGY,NRGY
```

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
CNRGY	41	208908.9163	29388.978	4589.787
NRGY	41	203370.2439	29095.213	4543.909

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
5538.6724	18801.816	2936.350	.793	.000	1.89	40	.067

---

* 6. NOTE: EIGHT-YEAR PERIOD REGRESSION RUN WITH
ALL VARIABLES. *

```
RUN NAME         REGRESX LACD
FILE NAME        REGLAC
VARIABLE LIST    BA,PD,YM,AREA,POP,HD,CD,DPRJ,EPRJ,NRGY
INPUT FORMAT     FREEFIELD
COMPUTE          PDAREA=PD*AREA
COMPUTE          PDPOP=PD*POP
COMPUTE          PDHD=PD*HD
COMPUTE          PDCD=PD*CD
COMPUTE          PDDPRJ=PD*DPRJ
MISSING VALUES   POP(0)
REGRESSION       METHOD=STEPWISE/VARIABLES=PDAREA,PDPOP,PDHD,PDCD,
                 PDDPRJ,AREA,POP,HD,CD,DPRJ,NRGY,PD/
                 REGRESSION=NRGY WITH PDAREA,PDPOP,PDHD,PDCD,
                 PDDPRJ,AREA,POP,HD,CD,DPRJ,PD
OPTIONS          2
STATISTICS       1,2,7
```

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

VARIABLE	MEAN	STANDARD DEV	CASES
PDAREA	4527919.6771	5275005.5934	96
PDPOP	12701.2917	14817.6313	96
PDHD	43.8021	104.2459	96
PDCD	127.7500	215.3548	96
PDDPRJ	0	0	96
AREA	10088391.7500	498001.5323	96
POP	30221.2414	1783.6473	87
HD	129.7917	172.5259	96
CD	252.5313	233.9846	96
DPRJ	0	0	96
NRGY	202019.3646	32938.7564	96
PD	.4271	.4973	96

CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

	PDAREA	PDPOP	PDHD	PDCD	PDDPRJ	AREA
PDPOP	.99765					
PDHD	.49692	.47767				
PDCD	.68526	.70670	-.17830			
PDDPRJ	99.00000	99.00000	99.00000	99.00000		
AREA	.90724	.89586	.52262	.56531	99.00000	
POP	-.25402	-.21961	-.21476	-.01850	99.00000	-.33549
HD	-.13207	-.14310	.39260	-.40651	99.00000	-.04221
CD	.16812	.18850	-.39054	.60070	99.00000	.10045
DPRJ	99.00000	99.00000	99.00000	99.00000	99.00000	99.00000
NRGY	.04006	.05472	-.14029	.30727	99.00000	.07485
PD	.99940	.99800	.48921	.69067	99.00000	.89506

	POP	HD	CD	DPRJ	NRGY
HD	-.22786				
CD	.34198	-.73357			
DPRJ	99.00000	99.00000	99.00000		
NRGY	.39672	-.11361	.62615	99.00000	
PD	-.25641	-.13699	.17282	99.00000	.03560

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

MEAN RESPONSE   202019.36458   STD. DEV.   32938.75640

VARIABLE PDDPRJ   IS A CONSTANT. INCLUSION LEVEL SET TO ZERO.

VARIABLE DPRJ   IS A CONSTANT. INCLUSION LEVEL SET TO ZERO.

VARIABLE(S) ENTERED ON STEP   1
CD

		ANOVA	DF	SUM SQUARES	MEAN SQ.	F
MULTIPLE R	.6261	REGRESSION	1.	.3658E+11	.36E+11	54.816
R SQUARE	.3921	RESIDUAL	85.	.5672E+11	.66E+09	SIG. 0
STD DEV	25833.1739					
ADJ R SQUARE	.3849	COEFF OF VARIABILITY		12.8PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	88.145	11.905	54.816	0	.62615	.11018
CONSTANT	179760.106	4087.734	1933.844	0		

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

VARIABLE(S) ENTERED ON STEP 2
HD

MULTIPLE R	.8067	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.6508	REGRESSION	2.	.6072E+11	.30E+11	78.284
STD DEV	19694.1775	RESIDUAL	84.	.3258E+11	.38E+09 SIG.	.000
ADJ R SQUARE	.6425	COEFF OF VARIABILITY		9.7PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	165.440	13.355	153.463	0	1.17522	.20681
HD	142.904	18.112	62.251	.000	.74850	.09181
CONSTANT	141692.848	5743.700	608.573	0		

* *

VARIABLE(S) ENTERED ON STEP 3
POP

MULTIPLE R	.8257	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.6818	REGRESSION	3.	.6361E+11	.21E+11	59.290
STD DEV	18912.3190	RESIDUAL	83.	.2968E+11	.35E+09 SIG.	0
ADJ R SQUARE	.6703	COEFF OF VARIABILITY		9.4PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	155.448	13.297	136.664	0	1.10425	.19432
HD	141.121	17.404	65.745	0	.73916	.09067
POP	3.463	1.218	8.089	.006	.18751	.51801
CONSTANT	39798.939	36248.545	1.205	.275		

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

```
DEP. VAR... NRGY

VARIABLE(S) ENTERED ON STEP   4
PDCD

MULTIPLE R     .8286 ANOVA          DF   SUM SQUARES   MEAN SQ.       F
R SQUARE       .6865 REGRESSION      4.    .6405E+11    .16E+11    44.896
STD DEV  18886.5283 RESIDUAL       82.    .2924E+11    .35E+09 SIG. .000
ADJ R SQUARE   .6712 COEFF OF VARIABILITY      9.3PCT

VARIABLE         B        S.E. B        F      SIG.       BETA   ELASTICITY

CD           164.974     15.821    108.739      0       1.17191     .20622
HD           142.610     17.433     66.923   .000        .74696     .09162
POP            3.037      1.275      5.675   .020        .16448     .45440
PDCD         -13.767     12.429      1.227   .271      -.09001    -.00871
CONSTANT   51810.666  37788.626      1.880   .174

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP   5
AREA

MULTIPLE R     .8385 ANOVA          DF   SUM SQUARES   MEAN SQ.       F
R SQUARE       .7030 REGRESSION      5.    .6559E+11    .13E+11    38.346
STD DEV  18496.4544 RESIDUAL       81.    .2771E+11    .34E+09 SIG.     0
ADJ R SQUARE   .6847 COEFF OF VARIABILITY      9.2PCT

VARIABLE         B        S.E. B        F      SIG.       BETA   ELASTICITY

CD           170.350     15.700    117.730      0       1.21010     .21294
HD           141.676     17.078     68.819      0        .74207     .09102
POP            3.812      1.301      8.584   .004        .20642     .57025
PDCD         -32.507     15.043      4.670   .034      -.21253    -.02056
AREA            .012       .005      4.495   .037        .17401     .57474
CONSTANT  -86545.071  75020.675      1.331   .252

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *
```

* NOTE: THE FOLLOWING THREE REGRESSION STEPS WERE NOT UTILIZED BECAUSE THE VARIABLES THAT ENTERED WERE NOT SIGNIFICANT. *

DEP. VAR... NRGY

VARIABLE(S) ENTERED ON STEP 6
PDPOP

MULTIPLE R	.8421	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.7092	REGRESSION	6.	.6616E+11	.11E+11	32.510
STD DEV	18417.9658	RESIDUAL	80.	.2713E+11	.33E+09	SIG. .000
ADJ R SQUARE	.6873	COEFF OF VARIABILITY		9.1PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	163.540	16.487	98.395	0	1.16172	.20443
HD	137.727	17.275	63.565	.000	.72139	.08849
POP	4.148	1.321	9.859	.002	.22461	.62052
PDCD	-19.019	18.218	1.090	.300	-.12435	-.01203
AREA	.022	.010	5.111	.026	.33430	1.10417
PDPOP	-.496	.382	1.692	.197	-.22330	-.03121
CONSTANT	-.196E+06	.11E+06	3.034	.085		

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

VARIABLE(S) ENTERED ON STEP 7
PDAREA

MULTIPLE R	.8428	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.7104	REGRESSION	7.	.6628E+11	.94E+10	27.681
STD DEV	18495.2775	RESIDUAL	79.	.2702E+11	.34E+09	SIG. 0
ADJ R SQUARE	.6847	COEFF OF VARIABILITY		9.2PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	162.915	16.591	96.416	0	1.15728	.20365
HD	138.676	17.425	63.337	0	.72636	.08910
POP	4.531	1.483	9.328	.003	.24535	.67781
PDCD	-15.211	19.450	.612	.437	-.09945	-.00962
AREA	.020	.010	3.872	.053	.30684	1.01347
PDPOP	-1.989	2.616	.578	.449	-.89468	-.12504
PDAREA	.004	.007	.333	.566	.68610	.09602
CONSTANT	-.190E+06	.11E+06	2.810	.098		

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

VARIABLE(S) ENTERED ON STEP 8
PDHD

MULTIPLE R	.8433	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.7112	REGRESSION	8.	.6635E+11	.82E+10	24.009
STD DEV	18587.1967	RESIDUAL	78.	.2694E+11	.34E+09	SIG. .000
ADJ R SQUARE	.6816	COEFF OF VARIABILITY		9.2PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CD	165.032	17.273	91.290	0	1.17232	.20630
HD	142.608	19.410	53.983	.000	.74695	.09162
POP	4.594	1.497	9.419	.003	.24878	.68729
PDCD	-25.649	29.598	.751	.389	-.16770	-.01622
AREA	.021	.010	3.940	.051	.31175	1.02970
PDPOP	-1.876	2.640	.505	.480	-.84375	-.11792
PDAREA	.004	.007	.353	.554	.71120	.09954
PDHD	-20.691	44.056	.221	.640	-.06548	-.00449
CONSTANT	-.197E+06	.11E+06	2.926	.091		

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

* * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * *

DEP. VAR... NRGY

SUMMARY TABLE.

STEP	VARIABLE	E/R	F	MULT-R	R-SQ	CHANGE	R	OVERALL F	SIG.
1	CD	E	54.816	.626	.392	.392	.626	54.816	0
2	HD	E	62.251	.807	.651	.259	-.114	78.284	.000
3	POP	E	8.089	.826	.682	.031	.397	59.290	0
4	PDCD	E	1.227	.829	.687	.005	.307	44.896	.000
5	AREA	E	4.495	.838	.703	.016	.075	38.346	0
6	PDPOP	E	1.692	.842	.709	.006	.055	32.510	.000
7	PDAREA	E	.333	.843	.710	.001	.040	27.681	0
8	PDHD	E	.221	.843	.711	.001	-.140	24.009	.000

APPENDIX C

DUMMY VARIABLES IN REGRESSION ANALYSIS

The most familiar variables used in regression analysis are quantitative variables, which represent quantities that can be measured or counted. Another type of variable which can be helpful in some types of problems is a qualitative variable, which indicates whether a certain condition exists. This qualitative variable is also called a dummy variable or a zero-one variable. As the latter implies, when the dummy variable is included in the regression equation, its value is set to either zero or one.

Y-Intercept Effects

Consider the following example regression equation where X_2 is a dummy variable:

$$Y = A + B_1X_1 + B_2X_2.$$

In this equation, the constant A is the Y-intercept value when the independent variables (X_1 and X_2) equal zero. If the condition of interest does not exist, then $X_2 = 0$ and the equation reverts to:

$$Y = A + B_1X_1,$$

where A is still the Y-intercept. If the condition exists, then $X_2 = 1$ and the equation is changed as follows:

$$Y = A + B_1X_1 + B_2(1),$$

$$Y = A + B_1X_1 + B_2,$$

$$Y = A + B_2 + B_1X_1,$$

$$Y = (A + B_2) + B_1X_1.$$

The last equation shows that the effect of an existing qualitative condition ($X_2 = 1$) is to change the Y-intercept from A to ($A + B_2$). Note that the slope (B_1) of the regression line is the same for both of the above situations.

<u>Slope/Crossproduct Effects</u>

The interrelationship between a dummy variable and a quantitative independent variable can also affect the slope of the regression equation (line). The regression equation must be structured differently, as in the following example, to allow for this effect:

$$Y = A + BX_1 + CX_2X_1.$$

Again, X_2 is the dummy variable with possible values of only zero and one. The apparently second order nature of the last term in the equation does not, in reality, destroy the linearity of the regression equation. Even though the crossproduct X_2X_1 appears to be of second order, the zero-one nature of X_2 merely serves to change the coefficient of the variable X_1 in the regression equation. Two alternative equations result, depending on the value of the dummy variable X_2:

If $X_2 = 0$, then

$Y = A + BX_1$, which has slope B.

If $X_2 = 1$, then

$Y = A + BX_1 + C(1)X_1$,

$Y = A + BX_1 + CX_1,$

$Y = A + (B + C)\ X_1$, which has slope $(B + C)$.

The crossproduct of the dummy variable (X_2) with the quantitative independent variable (X_1), then serves to change the slope, or "B coefficient," of the regression equation (line). In the above example, if both B and C are positive and $X_2 = 1$, an increase in X_1 would produce a greater increase in Y than if $X_2 = 0$.

The two dummy variable effects described above can be combined in the same regression model to allow for changes in both the intercepts and slopes of that model (16:571-573).

APPENDIX D

INTERVIEWS WITH EMCS SUPERVISORS
AND OPERATORS (23 JUNE 1983)

The present supervisors at the eight selected EMCS bases are given in the following table. This information was obtained from Mr. Larry Strothers and from making phone calls to the numbers he provided.

Base	Supervisor	Autovon no.	Office Symbol
Keesler	John Breal	868-4179	DEMC
Lackland	Jerry Smith	473-2568	DEMLC
Charleston	George Albright	583-3367	DEME
Scott	John Avolio	638-3463	DEMC
McGuire	Pete Servidone	440-2578	DEMU
Offutt	Dean Sunde	271-3945	DEMC
McClellan	Dick Steele	633-2210	DEMD
Air Force Academy	Capt. Ramsey	259-4426	DEMAE

Each of these bases were called on 23 June 1983 to talk to experienced personnel on the different EMCS's at each base to obtain their subjective opinion on the past and present status of their EMCS. When the word operator is used it means the personnel that run the EMCS while the use of the words shop personnel means the personnel that repair, calibrate, or replace any parts on the EMCS. The EMCS supervisor is the same as the EMCS systems engineer in this appendix.

The chief operator contacted at Keesler was Mr. John Breal, who is temporarily filling the supervisor job until a

new one is hired. The supervisor's job is a GS-12 position. The system operates under the Operations branch of Civil Engineering. During the last two years the system has been running at its 100% intended facility capacity which is 115 buildings. The two years before that the system was operating in only 60% of the 115 buildings. The system became operational four years ago. At present the system is only down two hours a month. Before two years ago it was down a considerable amount of time. John believes that the system is now running quite well.

At Charleston the supervisor, Mr. George Albright was contacted. Mr. Albright holds a GS-12 position and has been there three years. The system operates under the Operations branch in Civil Engineering. The system became operational nine years ago but it didn't operate at full capacity until five years ago. Since it became fully operational the system has had very little down time. Out of 1200 points being monitored only about 30 points are operating incorrectly on an average. George is quite pleased with the system operation.

At Lackland Mr. Jerry Smith was contacted. His job is a WS-11 position. The EMCS operates under the Operations branch of Civil Engineering. Lackland is under the San Antonio Real Property Management Agency (SARPMA). The system was only at 50% of its intended facility capacity when it became operational in 1979. The system did not operate

at full facility capacity until February 1981. The system monitors 7,500 points of which on the average 1%-3% are estimated to be operating incorrectly. The system down time averages only one hour a month. There are at present four operators and five shop personnel. There are four vacant positions in the shop which contribute to the number of inoperative points. The supervisor believes the number of points down should be less than one percent, but he is satisfied with the present operation of the EMCS itself.

At McGuire, Mr. Pete Servidone was contacted. His job is a GS-12 position. The system is under the Operations branch of Civil Engineering. The system was operating in 1975 with Honeywell operating it under contract until 1978. From 1978 to 1981 the base had several small business contractors run the EMCS. There were many problems when small business contractors ran the system. They did not maintain the system and because the contract was so badly written there was no way to enforce proper functioning of the system. In October 1981, the EMCS was changed to being run in house but was only operating at 50% of its intended facility capacity. The system did not run at full facility capacity until August 1982. The original CPU was a Delta 2000 (Honeywell), for which the programs could not be either changed or upgraded. A Delta 1000 (Honeywell) was installed in October 1981 which was programable. Another problem is that many of the 1000 points are receiving erroneous

information because many of the HVAC local controls have been bypassed by HVAC shop personnel. The EMCS supervisor is slowly getting these bypassed controls corrected as they are being discovered. He needs more money to really have the system operating properly. Pete believes the best way to operate the system is to keep it in house where the Air Force would maintain control of the system. This base is scheduled to receive another more modern computer this year. He has only one operator so the system only runs during the day. There are seven shop personnel of which two are fully qualified computer technicians (WG-11 positions) which are recent acquisitions. He now has the ability to maintain the system. The operators and shop personnel received little training until recently. Pete was glad to share his problems and he believes things are heading in the right direction. Since August of 1982 he believes the main system has been running well.

At Scott, Mr. John Avolio and the EMCS contractor were contacted. Mr. Avolio, the supervisor has had the position for two and a half years. The EMCS contractor believes the supervisor is the one that has been instrumental in bringing the system up to proper operation. His job is a GS-12 position. The system operates under the Operations branch of Civil Engineering. The system became operational four years ago but did not operate at intended capacity until two years ago. The system monitors approximately 2400 points.

The system only operates during the day. Before John no one really knew how to operate the system. There are five operators with a chief operator and seven or eight shop personnel. The base personnel did not like the system because they lost control of the temperature they wanted. Some of the base personnel learned how to bypass the controls. Most of these bypassing problems have been taken care of now. The system has very little down time.

At Offutt Mr. Dean Sunde (supervisor) and Mr. Joe Hamlin (chief operator) were contacted. The supervisor has a GS-11 position. The system operates under the Operations branch of Civil Engineering. The system became operational in March of 1978 at 60% facility capacity. It had many communication line problems which took to November 1981 to correct. The telephone lines originally transmitted at 300 baud which is what caused the problem but when the lines were changed to 600 baud the problem was corrected. Mr. Joe Hamlin is the only operator so the system only operates during the day. The system is maintained under a service contract. The computer is a Delta 5100 (Honeywell) which is fully programmable. There are approximately 1500 points of which an average of only 12 points are believed to be operating incorrectly. The system is down less than one hour a month. Both Mr. Smith and Mr. Hamlin agree that they think they have had a properly operating system since October 1981. They would like to do more but they are undermanned.

At McClellan, Mr. Dick Steele, the supervisor was contacted. He has a GS-12 position. The system operates under the Operations branch of Civil Engineering. The system became operational in 1977 but not at full capacity until late 1978. There are 4000 points in 20 buildings being controlled. The system is down less than one hour a month. On an average there are five points operating incorrectly. There are 21 shop personnel who are also WG-11's. The original computer was a Johnson JC-80 but on 25 March 1983 they went to a Johnson Modcom 720. Both systems have been good according to Dick. His system is different from other systems in that the base fire alarm system is connected into it rather than a separate fire alarm system.

At the Air Force Academy, Capt. Ramsey, the present supervisor was contacted. The supervisory job has been either filled by a GS-12 civilian or a military person. There has been seven different supervisors since the system became operational in March of 1978. It is scheduled to go back to a civilian position this year. The system has operated under the Engineering branch and the Operational branch of Civil Engineering. Presently it is operating under the Operations branch. The original computer was a Delta 2500 (Honeywell) which monitored 2500 points in five buildings. There were many problems under this system. In March of 1979 the computer was replaced with a Digital 11 which monitors 3500 points in 22 buildings. He believes there are

only 20-30 points operating incorrectly on an average. There are six operator positions of which only four are filled. There has been a 100% turnover in operators since 1978. The operator positions were used to hire female and minority persons to give them upward mobility. The problem has been that many do not like the job and quit or transfer. Three shop personnel maintain the system. The past and present system up until January 1983 did not use any of the energy controls. This means the system has not been used for energy management for the duration of the period covered for this thesis. The present system is down only three or four hours a month.

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